USDC SCAN INDEX SHEET

QUALCOMM INC

TELEFONAKTIEBOLAGET

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3:96-CV-02064

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ORIGINAL

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SOUTHERN DISTRICT OF CALIFORNIA
BY DEPUTY

UNITED STATES DISTRICT COURT

SOUTHERN DISTRICT OF CALIFORNIA

QUALCOMM Incorporated, Plaintiff, v. TELEFONAKTIEBOLAGET LM ERICSSON, and ERICSSON, INC., Defendants.	No. '962064 K CGA COMPLAINT FOR: (1) DECLARATORY RELIEF FOR PATENT INVALIDITY AND NON-INFRINGEMENT[U.S. PATENT NO. 5,430,760]; (2) DECLARATORY RELIEF FOR PATENT INVALIDITY AND NON-INFRINGEMENT [U.S. PATENT NO. 5,551,073]; (3) DECLARATORY RELIEF FOR PATENT INVALIDITY AND NON-INFRINGEMENT [U.S. PATENT NO. 5,193,140]; (4) DECLARATORY RELIEF (ESTOPPEL); AND (5) UNFAIR COMPETITION JURY TRIAL DEMANDED

Plaintiff QUALCOMM, Inc. alleges:

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JURISDICTION AND VENUE

1. This Complaint seeks declamatory relief under the Declaratory Judgment Act, Title 28, United States Code, Sections 2201 and 2202. This Court has jurisdiction of the claims asserted herein under Title 28, United States Code, Sections 1331 and 1338(a).

2. Venue is proper in this District under Title 28, United States Code, Sections 1391(a), 1391(b) and 1400(b).

THE PARTIES

3. Plaintiff QUALCOMM Inc. ("QUALCOMM") is a Delaware corporation. QUALCOMM maintains its headquarters and principal place of business in San Diego, CA. QUALCOMM develops, manufactures, markets, licenses, and operates advanced communications systems and products based on its proprietary digital wireless technologies.

4. Plaintiff is informed and believes that defendant Telefonaktiebolaget LM Ericsson is a corporation that is organized under the laws of Sweden and which maintains its principal place of business in Stockholm, Sweden.

5. Plaintiff is informed and believes that defendant Ericsson, Inc. is a corporation that maintains its principal place of business at Richardson, Texas. QUALCOMM is informed and believes that defendant Ericsson, Inc. is qualified to and does conduct business in the State of California and this District. QUALCOMM is further informed and believes that Defendant Ericsson, Inc. is the successor-in-interest of Ericsson Radio Systems, Inc.

6. Plaintiff is informed and believes that defendant Telefonaktiebolaget LM Ericsson owns or otherwise dominates and controls defendant Ericsson, Inc.. Unless otherwise indicated herein, QUALCOMM shall hereinafter collectively refer to defendants Ericsson, Inc. and Telefonaktiebolaget LM Ericsson as "the Ericsson defendants."

BACKGROUND

7. As part of its core business strategy in the field of wireless digital communications, QUALCOMM has developed a proprietary application of Code Division Multiple Access (CDMA) technology for use in mobile and fixed wireless communication systems. Such systems based on the

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Company's CDMA technology provide greater capacity and improved quality and reliability compared to existing analog systems and other digital wireless systems.

8. The telecommunications industry has recognized and acknowledged the great success and technological advance represented by QUALCOMM's development of its proprietary CDMA technology. Indeed, the Telecommunication Industry Association,, a leading organization in the telecommunications industry working on the development and promulgation of industry technical standards, has recognized the significant advance represented by QUALCOMM's CDMA technology through the adoption in 1993 of the TIA Interim Standard-95 ("IS-95"). (The original IS-95 standard has now "matured" by amendment to the current standard "IS-95-A.") Additional standards based on IS-95-A, including but not limited to the ANSI J-STB-008 standard for the new PCS wireless systems, have subsequently been adopted. (All such standards are referred to hereinafter as "IS-95-A.")

9. QUALCOMM is currently developing, marketing and manufacturing wireless communications infrastructure and subscriber equipment based on its proprietary and patented CDMA technology and has licensed its proprietary CDMA technology to major telecommunications equipment suppliers for incorporation into their wireless communications products. Such equipment consists of products such as the QUALCOMM Mobility System (which includes various infrastructure products and components) and various handheld CDMA telephones including the QCP-800 and QCP-1900 portable telephones. In addition, QUALCOMM has developed Application Specific Integrated Circuits (ASICs) for CDMA applications that it sells to its licensees for use in manufacturing CDMA infrastructure and subscriber equipment. QUALCOMM shall hereinafter collectively refer to the foregoing equipment and products as "QUALCOMM's CDMA products." In general, QUALCOMM has designed its CDMA products to comply with IS-95-A requirements.

THE PATENTS

10. QUALCOMM is informed and believes, and based thereon alleges, that, on or about July 4, 1995, the United States Patent Office issued United States Letters Patent Number 5,430,760 entitled "Random Access in Mobile Radio Telephone Systems." (QUALCOMM hereinafter refers to United States Patent No. 5,430,760 as "the '760 patent.") QUALCOMM is further informed and believes, and based thereon alleges, that Ericsson claims to be the owner, by assignment or

otherwise, of the '760 patent. QUALCOMM has attached a true and correct copy of the '760 patent as Exhibit "A" to this Complaint.

11. QUALCOMM is informed and believes, and based thereon alleges, that, on or about August 27, 1996, the United States Patent Office issued United States Letters Patent Number 5,551,073 entitled "Authentication Key Entry In Cellular Radio System." (QUALCOMM hereinafter refers to United States Patent No. 5,551,073 as "the '073 patent.") QUALCOMM is further informed and believes, and based thereon alleges, that Ericsson claims to be the owner, by assignment or otherwise, of the '073 patent. QUALCOMM has attached a true and correct copy of the '073 patent as Exhibit "B" to this Complaint.

12. QUALCOMM is informed and believes, and based thereon alleges, that, on or about March 9, 1993, the United States Patent Office issued United States Letters Patent Number 5,193,140 entitled "Excitation Pulse Positioning Method in a Linear Predictive Speech Coder." (QUALCOMM hereinafter refers to United States Patent No. 5,193,140 as "the '140 patent.") QUALCOMM is further informed and believes, and based thereon alleges, that Ericsson claims to be the owner, by assignment or otherwise, of the '140 patent. QUALCOMM has attached a true and correct copy of the '140 patent as Exhibit "C" to this Complaint.

Count I

(Declaratory Relief Regarding the '760 Patent)

13. QUALCOMM incorporates by reference the allegations set forth in Paragraphs 1 through 11, inclusive, of this Complaint as though set forth in full herein.

14. On repeated occasions in the months prior to the filing of this complaint, Ericsson has contacted QUALCOMM and expressed its contention that the '760 patent constitutes, in Ericsson's terms, a so-called "blocking" or "essential" patent, a license to which Ericsson contends is required in order to practice the IS-95-A standard. On still further occasions, Ericsson has specifically contended that one or more of QUALCOMM's CDMA products and those of QUALCOMM's licensees infringe the '760 patent. QUALCOMM is further informed and believes that Ericsson has contacted various, if not all, of QUALCOMM's licensees and expressed similar contentions to those licensees.

15. Based on the foregoing contention and related conduct of Ericsson, QUALCOMM has formed the reasonable apprehension and belief that Ericsson will sue QUALCOMM for infringement of the '760 patent.

16. As set forth above, an actual controversy exits between QUALCOMM, on the one hand, and the Ericsson defendants, on the other hand. QUALCOMM has summarized the contentions of the parties in the following paragraphs.

17. QUALCOMM contends that practicing CDMA technology in compliance with the specification of IS-95-A does not and will not infringe the '760 patent.

18. Without limiting the generality of the foregoing averment, QUALCOMM specifically contends that its IS-95-A compliant CDMA products do not and will not infringe the '760 patent.

19. QUALCOMM contends that the '760 patent is invalid because it fails to meet the requirements of Part II of Title 35 of the United States Code, including, but not limited to, one or more requirements for validity as stated in 35 U.S.C. Sections 101, 102, 103 and 112.

20. QUALCOMM further contends that, by reason of the proceedings in the United States Patent and Trademark Office during the prosecution of the application which resulted in the '760 patent, and by reason of the admissions and representations therein made by or on behalf of the applicant for the '760 patent, Ericsson is estopped from construing the claims of the '760 patent, even if this were otherwise possible, to cover and include any acts by QUALCOMM.

21. QUALCOMM also contends that the products and methods of its CDMA products compliant with IS-95-A, are so are different in principle from those disclosed in the '760 patent that said products function in a substantially different way from the '760 patent.

22. QUALCOMM still further contends that by reason of Ericsson's acts and conduct, Ericsson is estopped by the doctrine of patent misuse from enforcing the '760 patent against QUALCOMM or its licensees.

23. As QUALCOMM more particularly sets forth in Count IV of this Complaint, QUALCOMM also contends that Ericsson is still further estopped from enforcing the '760 patent against QUALCOMM or its licensees by reason of the Mutual Nondisclosure Agreement dated December 4, 1989 between QUALCOMM and Ericsson's predecessor-in-interest, Ericsson Radio

Systems, Inc. As set forth in that agreement, Ericsson Radio Systems, Inc. agreed and acknowledged that QUALCOMM's specific implementation of CDMA Technology and Spread Spectrum techniques in conjunction with any telephone or cellular radio telephone or mobile radio product or service, including, but not limited to, QUALCOMM's techniques for soft handoff, interference control, voice activity detection, power control, multiple receivers for multipath mitigation and CDMA signal design, PN sequence generation, pilot carrier and CDMA synchronization, is and was proprietary to QUALCOMM.

24. QUALCOMM is informed and believes, and based thereon alleges, that the Ericsson defendants deny each of the foregoing contentions contained in paragraphs 16 through 21.

25. As a result of the facts alleged herein, an actual, valid and justiciable controversy has arisen and now exists between QUALCOMM and the Ericsson defendants with respect to their respective rights, duties, obligations and liabilities regarding the parties' contentions.

26. QUALCOMM desires a judicial determination of the foregoing controversy and requests that the Court issue a declaration of the parties' respective rights with respect to all such matters as alleged hereinabove. A judicial declaration is necessary and appropriate a this time in order that QUALCOMM may determine the extent, nature and scope of its rights and duties with respect to the foregoing dispute and to, among other things, remove the cloud that the foregoing dispute places on the conduct of QUALCOMM's business, particularly in light of Ericsson's repeated claims of infringement with respect to the '760 patent.

27. QUALCOMM has no adequate remedy at law. The aforesaid conduct of the Ericsson defendants has caused and, if not enjoined, will continue to cause, irreparable damage to the rights of QUALCOMM and its CDMA licensees.

Count II

(Declaratory Relief Regarding the '073 Patent)

28. QUALCOMM incorporates by reference the allegations set forth in Paragraphs 1 through 11, inclusive, of this Complaint as though set forth in full herein.

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29. Prior to the filing of this complaint, Ericsson has contacted QUALCOMM and expressed Ericsson's contention that one or more of QUALCOMM's CDMA products and those of QUALCOMM's licensees infringe the '073 patent.

30. Based on the foregoing contention of Ericsson and related conduct of Ericsson, QUALCOMM has formed the reasonable apprehension and belief that Ericsson will sue QUALCOMM for infringement of the '073 patent.

31. As set forth above, an actual controversy exits between QUALCOMM, on the one hand, and the Ericsson defendants, on the other hand. QUALCOMM has summarized the contentions of the parties in the following paragraphs.

32. QUALCOMM contends that practicing CDMA technology in compliance with the specification of IS-95-A does not and will not infringe the '073 patent.

33. Without limiting the generality of the foregoing averment, QUALCOMM specifically contends that its IS-95-A compliant CDMA products do not and will not infringe the '073 patent.

34. QUALCOMM contends that the '073 patent is invalid because it fails to meet the requirements of Part II of Title 35 of the United States Code, including, but not limited to, one or more requirements for validity as stated in 35 U.S.C. Sections 101, 102, 103 and 112.

35. QUALCOMM further contends that, by reason of the proceedings in the United States Patent and Trademark Office during the prosecution of the application which resulted in the '073 patent, and by reason of the admissions and representation therein made by or on behalf of the applicant for the '073 patent, Ericsson is estopped from construing the claims of the '073 patent, even if this were otherwise possible, to cover and include any acts by QUALCOMM.

36. QUALCOMM also contends that the products and methods of its CDMA products compliant with IS-95-A, are so different in principle from those disclosed in the '073 patent that said products function in a substantially different way from the '073 patent.

37. QUALCOMM still further contends that by reason of Ericsson's acts and conduct, Ericsson is estopped by the doctrine of patent misuse from enforcing the '073 patent against QUALCOMM or its licensees.

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38. As QUALCOMM more particularly sets forth in Count IV of this Complaint, QUALCOMM also contends that Ericsson is still further estopped from enforcing the '073 patent against QUALCOMM or its licensees by reason of the Mutual Nondisclosure Agreement dated December 4, 1989 between QUALCOMM and Ericsson's predecessor-in-interest, Ericsson Radio Systems, Inc. As set forth in that agreement, Ericsson Radio Systems, Inc. agreed and acknowledged that QUALCOMM's specific implementation of CDMA Technology and Spread Spectrum techniques in conjunction with any telephone or cellular radio telephone or mobile radio product or service, including, but not limited to, QUALCOMM's techniques for soft handoff, interference control, voice activity detection, power control, multiple receivers for multipath mitigation and CDMA signal design, PN sequence generation, pilot carrier and CDMA synchronization, is and was proprietary to QUALCOMM.

39. QUALCOMM is informed and believes, and based thereon alleges, that the Ericsson defendants deny each of the foregoing contentions contained in paragraphs 30 through 35.

40. As a result of the facts alleged herein, an actual, valid and justiciable controversy has arisen and now exists between QUALCOMM and the Ericsson defendants with respect to their respective rights, duties, obligations and liabilities regarding the parties' contentions.

41. QUALCOMM desires a judicial determination of the foregoing controversy and requests that the Court issue a declaration of the parties' respective rights with respect to all such matters as alleged hereinabove. A judicial declaration is necessary and appropriate a this time in order that QUALCOMM may determine the extent, nature and scope of its rights and duties with respect to the foregoing dispute and to, among other things, remove the cloud that the foregoing dispute places on the conduct of QUALCOMM's business, particularly in light of Ericsson's claim of infringement with respect to the '073 patent.

42. QUALCOMM has no adequate remedy at law. The aforesaid conduct of the Ericsson defendants has caused and, if not enjoined, will continue to cause, irreparable damage to the rights of QUALCOMM and its CDMA licensees.

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Count III

(Declaratory Relief Regarding the '140 Patent)

43. QUALCOMM incorporates by reference the allegations set forth in Paragraphs 1 through 11, inclusive, of this Complaint as though set forth in full herein.

44. Prior to the filing of this complaint, Ericsson contacted the Telecommunications Industry Association and asserted that the '140 patent is essential to practice the TIA's IS-127 standard, a standard related to IS-95-A. Ericsson has also contacted QUALCOMM and expressed its contention that the '140 patent constitutes, in Ericsson's terms, a so-called "blocking" or "essential" patent, a license to which Ericsson contends is required by QUALCOMM in order to practice IS-95-A and/or the related standards.

45. Based on the foregoing contention and related conduct of Ericsson, QUALCOMM has formed the reasonable apprehension and belief that Ericsson will sue QUALCOMM for infringement of the '140 patent.

46. As set forth above, an actual controversy exits between QUALCOMM, on the one hand, and the Ericsson defendants, on the other hand. QUALCOMM has summarized the contentions of the parties in the following paragraphs.

47. QUALCOMM contends that practicing CDMA technology in compliance with the specification of IS-95-A and the related standards does not and will not infringe the '140 patent.

48. Without limiting the generality of the foregoing averment, QUALCOMM specifically contends that its IS-95-A compliant CDMA products do not and will not infringe the '140 patent.

49. QUALCOMM contends that the '140 patent is invalid because it fails to meet the requirements of Part II of Title 35 of the United States Code, including, but not limited to, one or more requirements for validity as stated in 35 U.S.C. Sections 101, 102, 103 and 112.

50. QUALCOMM further contends that, by reason of the proceedings in the United States Patent and Trademark Office during the prosecution of the application which resulted in the '140 patent, and by reason of the admissions and representations therein made by or on behalf of the applicant for the '140 patent, Ericsson is estopped from construing the claims of the '140 patent, even if this were otherwise possible, to cover and include any acts by QUALCOMM.

51. QUALCOMM also contends that the products and methods of its CDMA products compliant with IS-95-A and the related standards, are so are different in principle from those disclosed in the '140 patent that said products function in a substantially different way from the '140 patent.

52. QUALCOMM still further contends that by reason of Ericsson's acts and conduct, Ericsson is estopped by the doctrine of patent misuse from enforcing the '140 patent against QUALCOMM or its licensees.

53. QUALCOMM is informed and believes, and based thereon alleges, that the Ericsson defendants deny each of the foregoing contentions contained in paragraphs 47 through 52.

54. As a result of the facts alleged herein, an actual, valid and justiciable controversy has arisen and now exists between QUALCOMM and the Ericsson defendants with respect to their respective rights, duties, obligations and liabilities regarding the parties' contentions.

55. QUALCOMM desires a judicial determination of the foregoing controversy and requests that the Court issue a declaration of the parties' respective rights with respect to all such matters as alleged hereinabove. A judicial declaration is necessary and appropriate a this time in order that QUALCOMM may determine the extent, nature and scope of its rights and duties with respect to the foregoing dispute and to, among other things, remove the cloud that the foregoing dispute places on the conduct of QUALCOMM's business, particularly in light of Ericsson's repeated claims of infringement with respect to the '140 patent.

56. QUALCOMM has no adequate remedy at law. The aforesaid conduct of the Ericsson defendants has caused and, if not enjoined, will continue to cause, irreparable damage to the rights of QUALCOMM and its CDMA licensees.

COUNT IV

(DECLARATORY RELIEF OF CONTRACTUAL AND EQUITABLE ESTOPPEL)

57. QUALCOMM incorporates by reference the allegations set forth in Paragraphs 1 through 11, inclusive, of this Complaint as though set forth in full herein.

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58. On or about December 4, 1989, defendant Ericsson, Inc.'s predecessor-in-interest, Ericsson Radio Systems, Inc., entered into a Mutual Nondisclosure Agreement with QUALCOMM. QUALCOMM has attached a true and correct copy of that agreement as Exhibit "D."

59. As set forth in that paragraph 5 of the December 4, 1989 agreement, Ericsson Radio Systems, Inc. agreed and acknowledged that QUALCOMM's specific implementation of CDMA Technology and Spread Spectrum techniques in conjunction with any telephone or cellular radio telephone or mobile radio product or service, including, but not limited to, QUALCOMM's techniques for soft handoff, interference control, voice activity detection, power control, multiple receivers for multipath mitigation and CDMA signal design including forward error correction, PN sequence generation, pilot carrier and CDMA synchronization, is and was proprietary to QUALCOMM.

60. By the December 4, 1989, agreement, Ericsson Radio Systems, Inc. further agreed that it not use any of QUALCOMM's proprietary information in any other manner than the limited manner set forth in that agreement.

61. As set forth above, an actual controversy exits between QUALCOMM, on the one hand, and the Ericsson defendants, on the other hand. QUALCOMM has summarized the contentions of the parties in the following paragraphs.

62. QUALCOMM contends that by reason of the aforementioned agreement and acknowledgment of the December 4, 1989 agreement, the Ericsson defendants are estopped by principles of contract and equity from asserting against QUALCOMM the prior invention, ownership or infringement of any of the Ericsson defendants' patents, including the '760 and '073 patents which they now contend "block," are "essential to" the practice of IS-95-A or are otherwise infringed by QUALCOMM.

63. QUALCOMM is informed and believes that the Ericsson defendants dispute the forgoing contentions.

64. As a result of the facts alleged herein, an actual, valid and justiciable controversy has arisen and now exists between QUALCOMM and the Ericsson defendants with respect to their respective rights, duties, obligations and liabilities regarding the parties' contentions.

65. QUALCOMM desires a judicial determination of the foregoing controversy and requests that the Court issue a declaration of the parties' respective rights with respect to all such matters as alleged hereinabove. A judicial declaration is necessary and appropriate a this time in order that QUALCOMM may determine the extent, nature and scope of its rights and duties with respect to the foregoing dispute and to, among other things, remove the cloud that the foregoing dispute places on QUALCOMM's conduct of it business, particularly in light of Ericsson's repeated claims of infringement with respect to the '760, '073 and other allegedly related Ericsson patents.

66. Through the December 4, 1989 agreement, QUALCOMM and Ericsson Radio Systems, Inc. further agreed that California law would govern the provisions of the Agreement. In addition, they further agreed that, should QUALCOMM prevail on any action to enforce or protect its rights under the agreement, it would recover its attorney's fees and costs in addition to its damages.

Count V

(Unfair Competition)

67. QUALCOMM incorporates by reference the allegations set forth in Paragraphs 1 through 11, inclusive, of this Complaint as though set forth in full herein.

68. The Ericsson defendants have acted as the leading telecommunications industry "champion" of a European wireless digital technology known as Global System for Mobile ("GSM"). QUALCOMM is informed and believes that the Ericsson defendants have built and designed their most commercially successful wireless communication products to the GSM standard.

69. The proponents of GSM, prominently including the Ericsson defendants, have historically touted that technology as "competitive" with QUALCOMM's proprietary CDMA technology and have claimed that it is superior to CDMA. Indeed over the recent years, the Ericsson defendants have sought to disparage QUALCOMM's CDMA technology and obstruct industry evaluation and acceptance of CDMA as an industry standard and "chill" further deployment of QUALCOMM's CDMA technology. The Ericsson defendants were motivated in this conduct by the realization that, if adopted as an industry standard, the inherent benefits and

advantages of QUALCOMM's CDMA technology over the older GSM technology would severely inhibit and impair future growth and proliferation of their GSM-based products and technology.

70. When the Ericsson defendants' efforts to "chill" the CDMA market failed to discourage both the Telecommunications Industry Association in its adoption of the IS-95 standard in accordance with QUALCOMM's CDMA technology and the commercial acceptance of that technology by leading wireless technology service providers such as AirTouch, NYNEX, Sprint, Primeco, Ameritech, and others, the Ericsson defendants added a new tactic in their scheme to further chill additional market adoption and deployment of QUALCOMM's CDMA technology. By this tactic, after historically disparaging QUALCOMM's CDMA technology, the Ericsson defendants suddenly boasted that they were the inventors of significant portions of QUALCOMM's CDMA technology.

71. For example, in August 1995 defendant Telefonaktiebolaget LM Ericsson's Interim Report for the six months ending June 30, 1995, the Ericsson defendants boasted of having an "advanced CDMA development" program which had resulted in "a significant number" of US. patents encompassing QUALCOMM's CDMA technology. Of particular concern, the Ericsson defendants claimed that "several [of those U.S. patents] represent[ed] blocking patents with the USA IS 95 standard, whereby future users of this technology must have a license from Ericsson." The timing of the Ericsson defendants' surprise announcement of an "advanced CDMA development program" and their vague reference to "a significant number" of CDMA patents reveals their anticompetitive motivation. At that time, two of the three largest U.S. PCS wireless communications network providers announced that they had selected IS-95-based CDMA technology over Ericsson's GSM technology for deployment in their PCS systems. In response, Ericsson announced that it would not make or sell IS-95 compliant products because they viewed QUALCOMM's CDMA technology as "unproven."

72. The Ericsson defendants knew and intended that their surprise claims of supposed ownership of so-called "blocking" patents would cause significant unrest and turmoil in the United States digital wireless market. QUALCOMM is informed and believes numerous third parties, including securities analysts with extensive knowledge of the United States wireless

communications market, contacted Ericsson to inquire as to the basis for Ericsson's claim and the identification of the allegedly "blocking" patents. Surprisingly, despite the absence of any legitimate basis to conceal or hide the identify of such patents, QUALCOMM is further informed and believes that the Ericsson defendants declined to identify the "mystery" CDMA patents about which it boasted.

73. This tactic of surprise disclosure of allegedly "blocking" patents coupled with the Ericsson defendants' refusal to identify such patents in response to analysts' inquiries was a specific and targeted effort by the Ericsson defendants to impede QUALCOMM and the burgeoning CDMA marketplace. Indeed, on the day that the Ericsson defendants released their Interim Report, trading on the shares of QUALCOMM public securities depressed the price of QUALCOMM common stock by nearly three dollars, representing a total loss of market capitalization to QUALCOMM and its shareholders of over 180 million dollars!

74. The Ericsson defendants did not stop their pattern of unfair and anticompetitive conduct to chill the CDMA marketplace following the issuance of the Interim Report. To the contrary, on August 21, 1995, QUALCOMM wrote to Ericsson requesting that Ericsson identify the supposed "blocking patents" which the Ericsson defendants reported in that Interim Report. In a series of letters between the Ericsson defendants and QUALCOMM, the Ericsson defendants first refused outright to identify the alleged patents and then insisted that it would identity those patents *only after* QUALCOMM agreed to keep the identity of those patents secret! This demand by the Ericsson defendants that QUALCOMM agree to keep the identity of the allegedly "blocking" patents secret was a further aspect of their effort to chill the CDMA marketplace. The unfair and anticompetitive nature of this insistence upon secrecy was particularly transparent in light of the fact that, as U.S. patents, all of the "secret" blocking patents were public documents about which Ericsson had no basis to claim any confidentiality whatsoever.

75. Ultimately, after QUALCOMM refused to agree to Ericsson's demand for secrecy, on November 14, 1995, the Ericsson defendants finally delivered to QUALCOMM a list of 21 U.S. patents which the Ericsson defendants claimed were all "relevant" to the IS-95-A standard. In addition, however, the Ericsson defendants stated that their list of 21 "relevant" patents included a

"considerable number of essential patents whose use would be required for the implementation of IS-95-A." Yet, Ericsson refused to identify which of its "laundry list" of patents comprised the set of "essential" patents. Thus, the Ericsson defendants continued their activities to chill the market by forcing QUALCOMM and the CDMA market at large to find the proverbial "essential needles" in the Ericsson defendants' "haystack" of alleged relevant patents.

76. On November 22, 1995, QUALCOMM quickly responded to the Ericsson defendants' identification of "relevant" patents with a request that, among other information, Ericsson identify those patents which Ericsson believed "would be required for the implementation of IS-95-A" along with some identification of the particular specifications of IS-95-A relevant to those patents. Although Ericsson ultimately responded on December 11, 1996 with a list of its so-called "essential patents" which it believed were necessary to implement the IS-95-A standard, it declined to substantiate its claims by identifying which -- if any -- of the specifications of IS-95-A were affected by those patents or providing any specific indication of which -- if any -- of QUALCOMM's products infringed those patents. Indeed, in subsequent correspondence with QUALCOMM, the Ericsson defendants insisted that QUALCOMM undertake an independent analysis without assistance from the Ericsson defendants to seek to find whatever tenuous relationship might exist between the Ericsson patents and the IS-95-A standard and QUALCOMM's CDMA products.

77. Ultimately, in early 1996, after further vehement objections from QUALCOMM, Ericsson agreed to provide QUALCOMM with more specific information regarding the basis upon which Ericsson claimed that its "essential" patents blocked the implementation of IS-95-A standard. However, by that time, the Ericsson defendants had effectively succeeded in perpetuating their "chill" over the worldwide and U.S. CDMA market during a critical 6-month period of worldwide wireless technology deployment.

78. The aforementioned conduct of the Ericsson defendants, and each of them, constitutes unfair competition under the laws of the State of California.

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79. By reason of the aforementioned unfair competition by the Ericsson defendants, and each of them, QUALCOMM has suffered damages well in excess of the jurisdictional limit of $50,000, according to proof at time of trial.

80. The Ericsson defendants, and each of them, committed the aforementioned conduct of unfair competition in conscious disregard of the rights and benefits of QUALCOMM. By reason of such conscious disregard, QUALCOMM is entitled to recover punitive and exemplary damages from each of the Ericsson defendants in an amount sufficient to punish and deter the Ericsson defendants and hold them up to public scorn, reprobation and ridicule sufficient to deter others from undertaking similar conduct in the future.

WHEREFORE, QUALCOMM prays as follows:

1. On its first count:

a) For a declaration that QUALCOMM does not and will not necessarily infringe the '760 patent by the manufacture, sale and distribution of its IS-95-A compliant CDMA products;

b) For a declaration that the '760 patent is invalid and/or unenforceable against QUALCOMM and its licensees;

c) For a temporary restraining order and a preliminary and permanent injunction enjoining and restraining the Ericsson defendants, their respective officers, agents, servants, employees and attorneys, and all persons acting in concert with them, and each of them:

i) From making any claim to any person or entity that QUALCOMM's CDMA products compliant with IS-95-A infringe the '760 patent;

ii) From interfering with, or threatening to interfere with the manufacture, sale, license, or use of QUALCOMM's CDMA products compliant with IS-95, by QUALCOMM, its distributors, customers, licensees, successors or assigns, and others; and

iii) From instituting or prosecuting any lawsuit or proceeding, placing in issue the right of QUALCOMM, its distributors, customers, licensees, successors or assigns, and others to make, use or sell QUALCOMM's CDMA products compliant with IS-95-A in the context of the '760 patent;

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2. On its Second Count:

a) For a declaration that QUALCOMM does not and will not necessarily infringe the '073 patent by the manufacture, sale and distribution of its IS-95-A compliant CDMA products;

b) For a declaration that the '073 patent is invalid and/or unenforceable against QUALCOMM and its licensees;

c) For a temporary restraining order and a preliminary and permanent injunction enjoining and restraining the Ericsson defendants, their respective officers, agents, servants, employees and attorneys, and all persons acting in concert with them, and each of them:

i) From making any claim to any person or entity that QUALCOMM's CDMA products compliant with IS-95-A infringe the '073 patent;

ii) From interfering with, or threatening to interfere with the manufacture, sale, license, or use of QUALCOMM's CDMA products compliant with IS-95, by QUALCOMM, its distributors, customers, licensees, successors or assigns, and others; and

d) From instituting or prosecuting any lawsuit or proceeding, placing in issue the right of QUALCOMM, its distributors, customers, licensees, successors or assigns, and others to make, use or sell QUALCOMM's CDMA products compliant with IS-95-A in the context of the '073 patent;

3. On its Third Count:

a) For a declaration that QUALCOMM does not and will not necessarily infringe the '140 patent by the manufacture, sale and distribution of its IS-95-A compliant CDMA products;

b) For a declaration that the '140 patent is invalid and/or unenforceable against QUALCOMM and its licensees;

c) For a temporary restraining order and a preliminary and permanent injunction enjoining and restraining the Ericsson defendants, their respective officers, agents, servants, employees and attorneys, and all persons acting in concert with them, and each of them:

i) From making any claim to any person or entity that QUALCOMM's CDMA products compliant with IS-95-A or the related standards infringe the '140 patent;

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ii) From interfering with, or threatening to interfere with the manufacture, sale, license, or use of QUALCOMM's CDMA products compliant with IS-95, by QUALCOMM, its distributors, customers, licensees, successors or assigns, and others; and

d) From instituting or prosecuting any lawsuit or proceeding, placing in issue the right of QUALCOMM, its distributors, customers, licensees, successors or assigns, and others to make, use or sell QUALCOMM's CDMA products compliant with IS-95-A or the related standards in the context of the '140 patent;

4. On its Fourth Count:

a) For a declaration that Ericsson is estopped from asserting against QUALCOMM's specific implementation of CDMA Technology and Spread Spectrum Techniques the prior invention, ownership or infringement of any of the Ericsson defendants' patents, including the '760 and '073 patents.

b) For a temporary restraining order and a preliminary and permanent injunction enjoining and restraining the Ericsson defendants, their respective officers, agents, servants, employees and attorneys, and all persons acting in concert with them, and each of them:

i) From making any claim to any person or entity that QUALCOMM's CDMA products complaint with IS-95-A infringe any Ericsson patent.

ii) From interfering with, or threatening to interfere with the manufacture, sale, license, or use of QUALCOMM's CDMA products compliant with IS-95, by QUALCOMM, its distributors, customers, licensees, successors or assigns, and others; and

iii) From instituting or prosecuting any lawsuit or proceeding, placing in issue the right of QUALCOMM, its distributors, customers, licensees, successors or assigns, and others to make, use or sell QUALCOMM's CDMA products compliant with IS-95-A in the context of the ERICSSON defendants' patents;

5. On its Fifth Count:

a) For general and special damages according to proof at time of trial;

b) For restitution of any amounts by which Ericsson has been unjustly enriched; and

c) For punitive and exemplary damages.

6. For recovery of QUALCOMM's attorneys' fees and costs of suit incurred herein; and

7. For such other and further relief as the Court may deem just and proper.

Dated: December 5, 1996

LLOYD R. DAY, JR. (90875)
MARTIN L. LAGOD (117296)
STEPHEN P. SWINTON (106398)
COOLEY GODWARD LLP

FRANK E. ROGOZIENSKI (51445)
FRANK E. ROGOZIENSKI, INC., A
PROFESSIONAL CORPORATION

By: ______________________
Stephen P. Swinton

Attorneys for Plaintiff
QUALCOMM Incorporated

DEMAND FOR JURY TRIAL

Plaintiff, QUALCOMM, Inc. hereby demands trial by jury on all claims and issues so triable.

Dated: December 5, 1996

LLOYD R. DAY, JR. (90875)
MARTIN L. LAGOD (117296)
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By: ______________________
Stephen P. Swinton

Attorneys for Plaintiff
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US005430760A

United States Patent [19]
Dent

[11] Patent Number: 5,430,760
[45] Date of Patent: Jul. 4, 1995

[54] RANDOM ACCESS IN MOBILE RADIO TELEPHONE SYSTEMS

[75] Inventor: Paul W. Dent, Stehag, Sweden

[73] Assignee: Ericsson GE Mobile Communications Inc., Paramus, N.J.

[21] Appl. No.: 222,008

[22] Filed: Apr. 4, 1994

Related U.S. Application Data

[63] Continuation of Ser. No. 867,149, Apr. 10, 1992.

[51] Int. Cl.[6] H04J 13/04; H04B 7/216
[52] U.S. Cl. 375/200; 455/54.2; 455/70
[58] Field of Search 375/1; 455/70, 54.2

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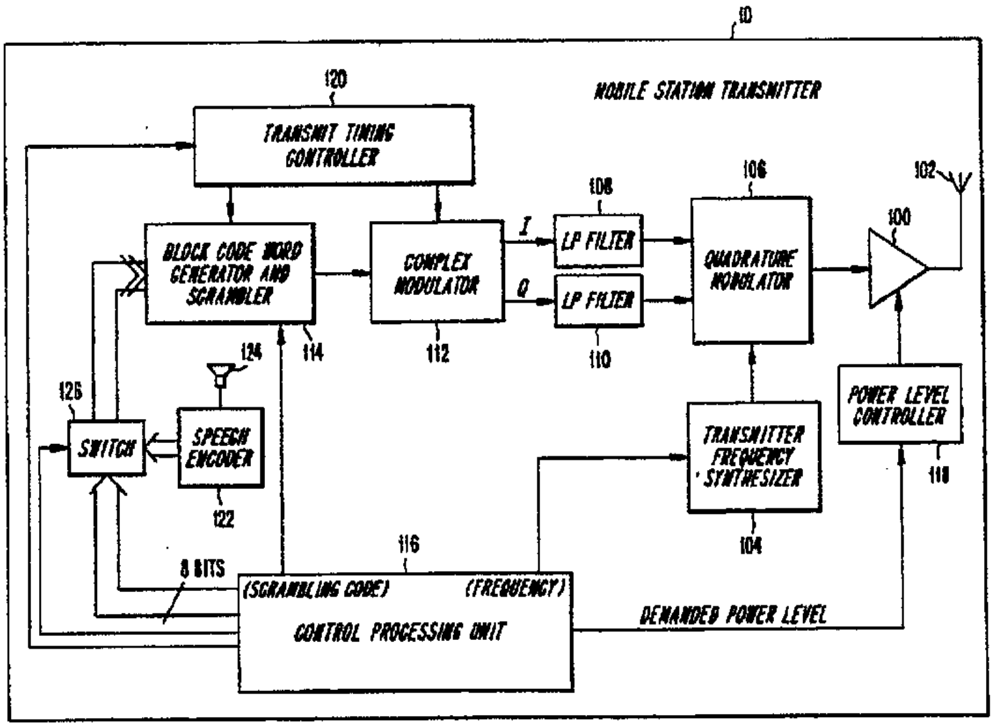
Primary Examiner—Gilberto Barrón, Jr.
Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis

[57] **ABSTRACT**

The present invention includes a system and method for minimizing interference between two radio stations, e.g., a mobile radio telephone and a fixed base station, at the initiation of a radio communication. A mobile station initiates a random access at the lowest power level and increases the transmission power level until the base station detects the access signal. Once detected, the power level of the message is maintained at the detected level so that the signal interference is avoided. The present invention also provides a mechanism for synchronizing random access communications between mobile stations and the base station despite variation in distances between the mobile and base stations.

43 Claims, 6 Drawing Sheets



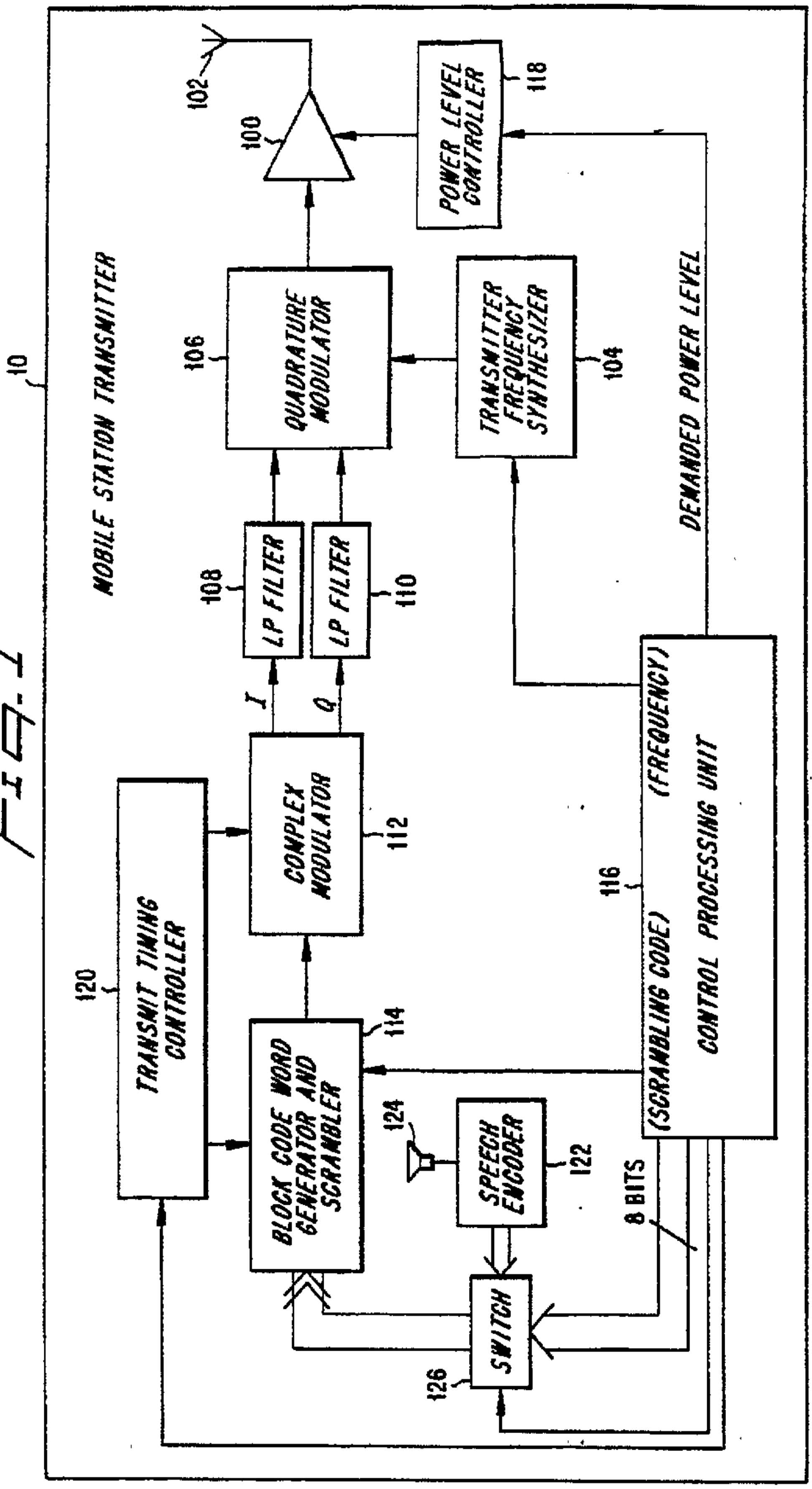

10
MOBILE STATION TRANSMITTER
102
100
POWER LEVEL CONTROLLER
118
QUADRATURE MODULATOR
106
TRANSMITTER FREQUENCY SYNTHESIZER
104
DEMANDED POWER LEVEL
LP FILTER
108
LP FILTER
110
I
Q
COMPLEX MODULATOR
112
(FREQUENCY)
CONTROL PROCESSING UNIT
116
(SCRAMBLING CODE)
TRANSMIT TIMING CONTROLLER
120
BLOCK CODE WORD GENERATOR AND SCRAMBLER
114
124
SPEECH ENCODER
122
8 BITS
SWITCH
126

FIG. 1

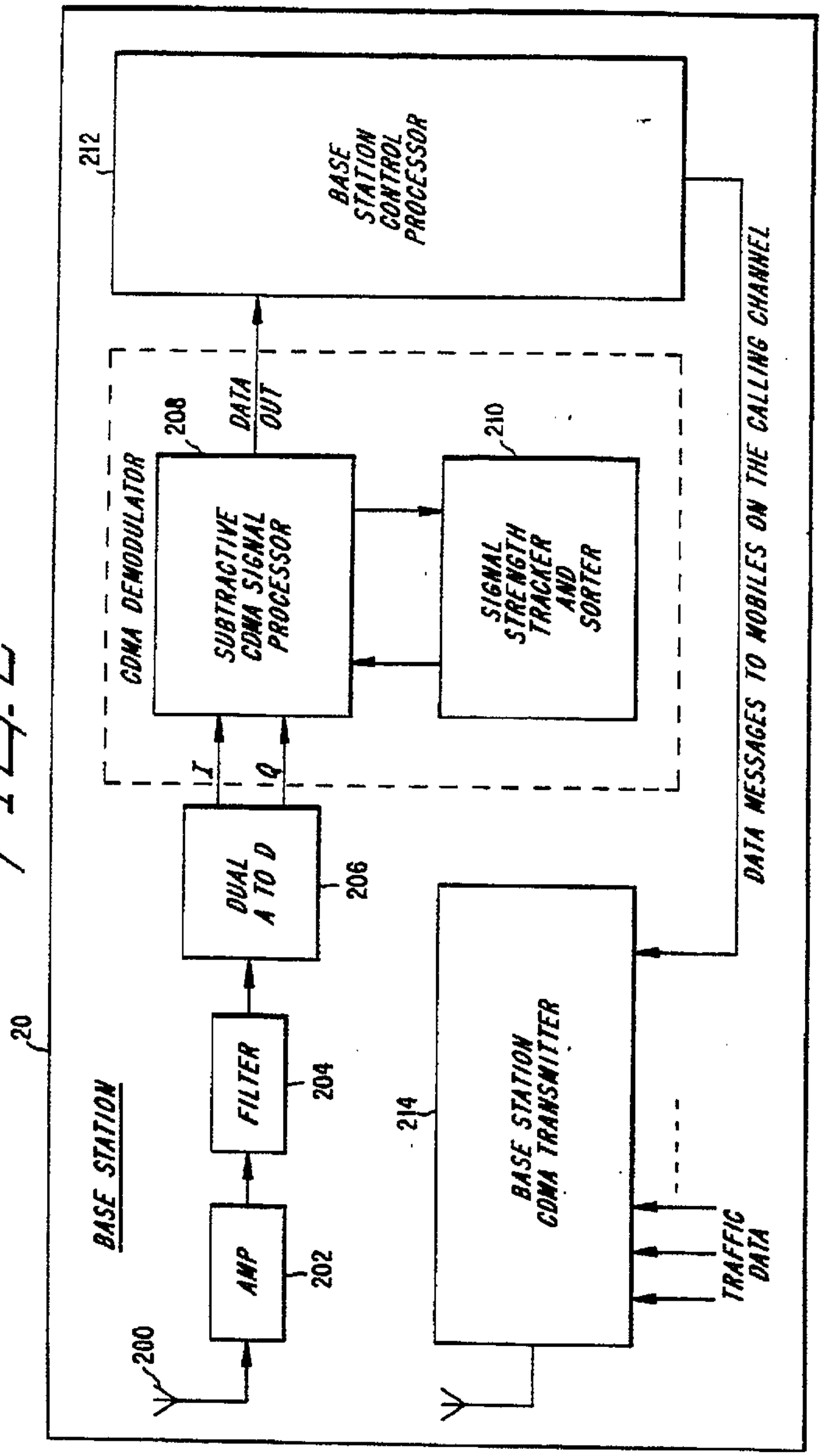

20
BASE STATION
200
AMP
202
FILTER
204
DUAL A TO D
206
I
Q
CDMA DEMODULATOR
SUBTRACTIVE CDMA SIGNAL PROCESSOR
208
DATA OUT
SIGNAL STRENGTH TRACKER AND SORTER
210
BASE STATION CONTROL PROCESSOR
212
BASE STATION CDMA TRANSMITTER
214
TRAFFIC DATA
DATA MESSAGES TO MOBILES ON THE CALLING CHANNEL

FIG. 2

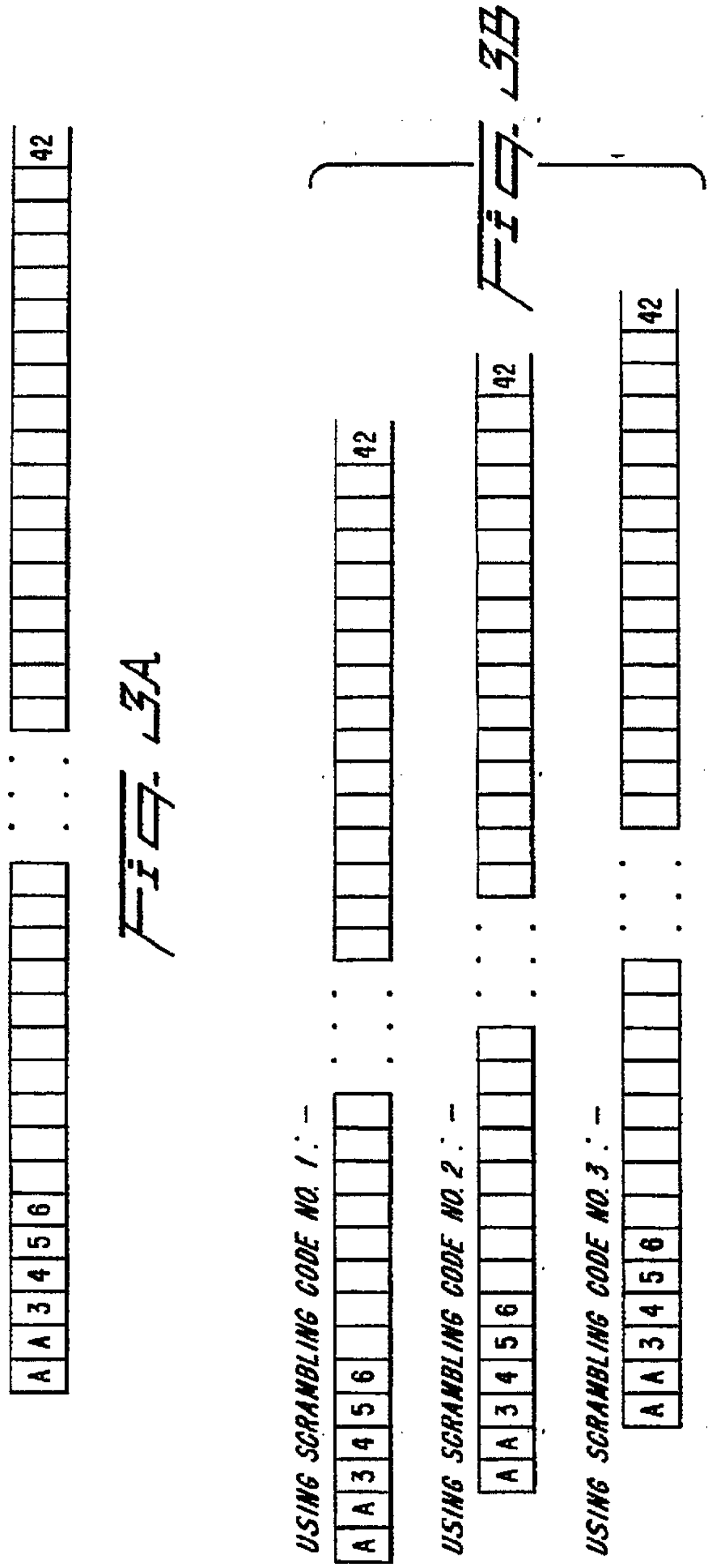

A
A
3
4
5
6
42
USING SCRAMBLING CODE NO. 1:
USING SCRAMBLING CODE NO. 2:
USING SCRAMBLING CODE NO. 3:

FIG. 3A

FIG. 3B

Fig. 4A

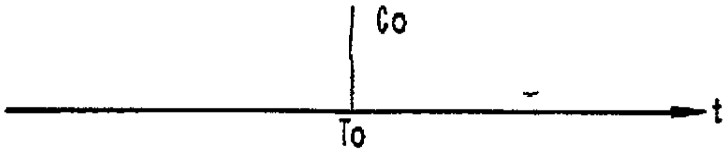


Fig. 4B

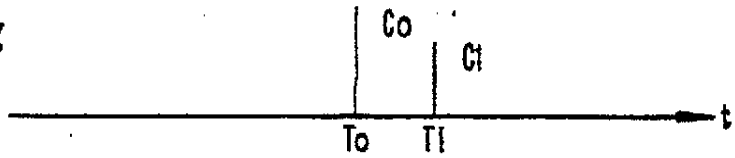


Fig. 4C

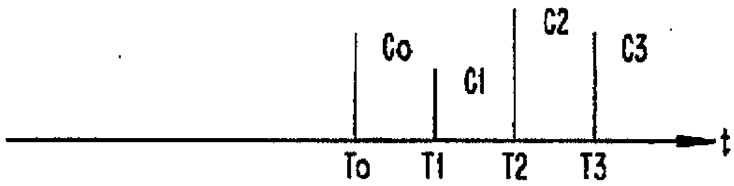
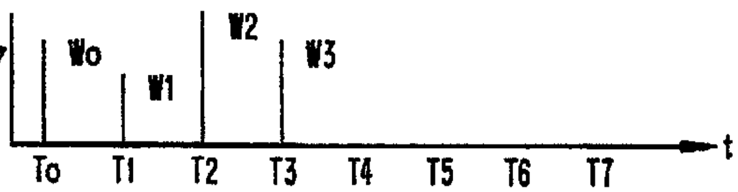


Fig. 4D

Fig. 4E



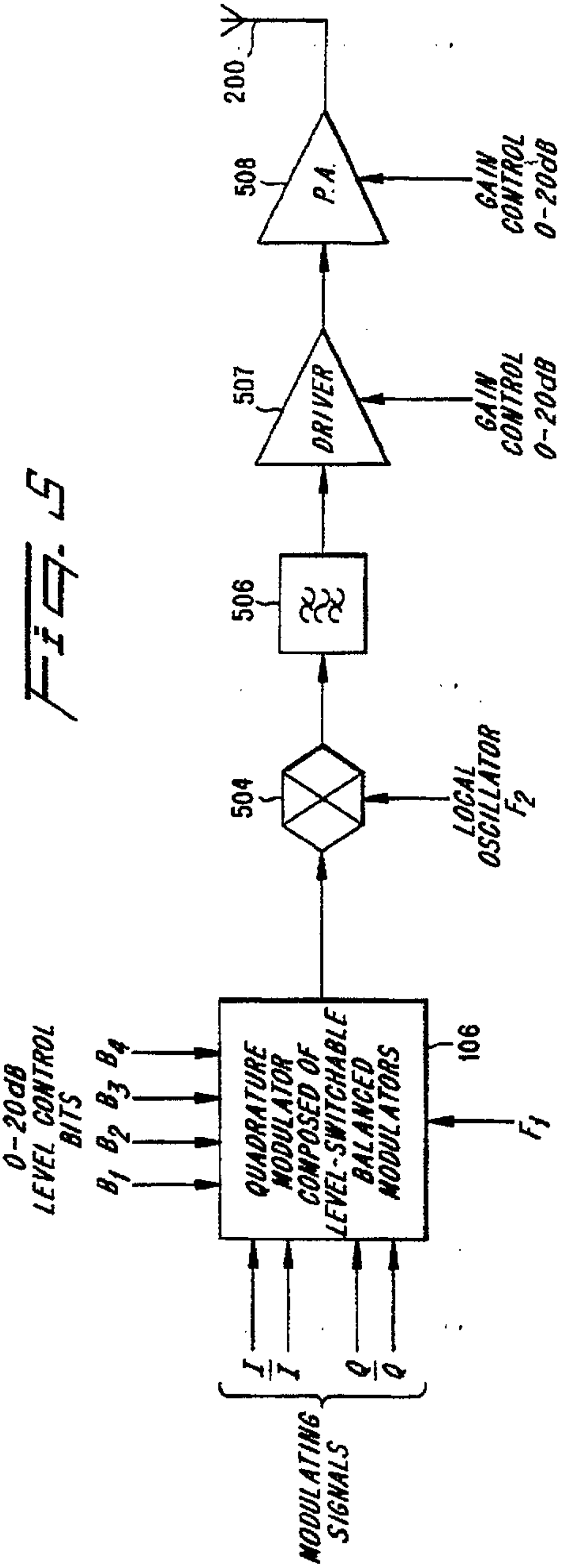

200
508
P.A.
GAIN CONTROL 0-20dB
507
DRIVER
GAIN CONTROL 0-20dB
506
504
LOCAL OSCILLATOR F_2
0-20dB LEVEL CONTROL BITS
B_1 B_2 B_3 B_4
QUADRATURE MODULATOR COMPOSED OF LEVEL-SWITCHABLE BALANCED MODULATORS
106
F_1
I $\bar{I}$ Q $\bar{Q}$
MODULATING SIGNALS

FIG. 5

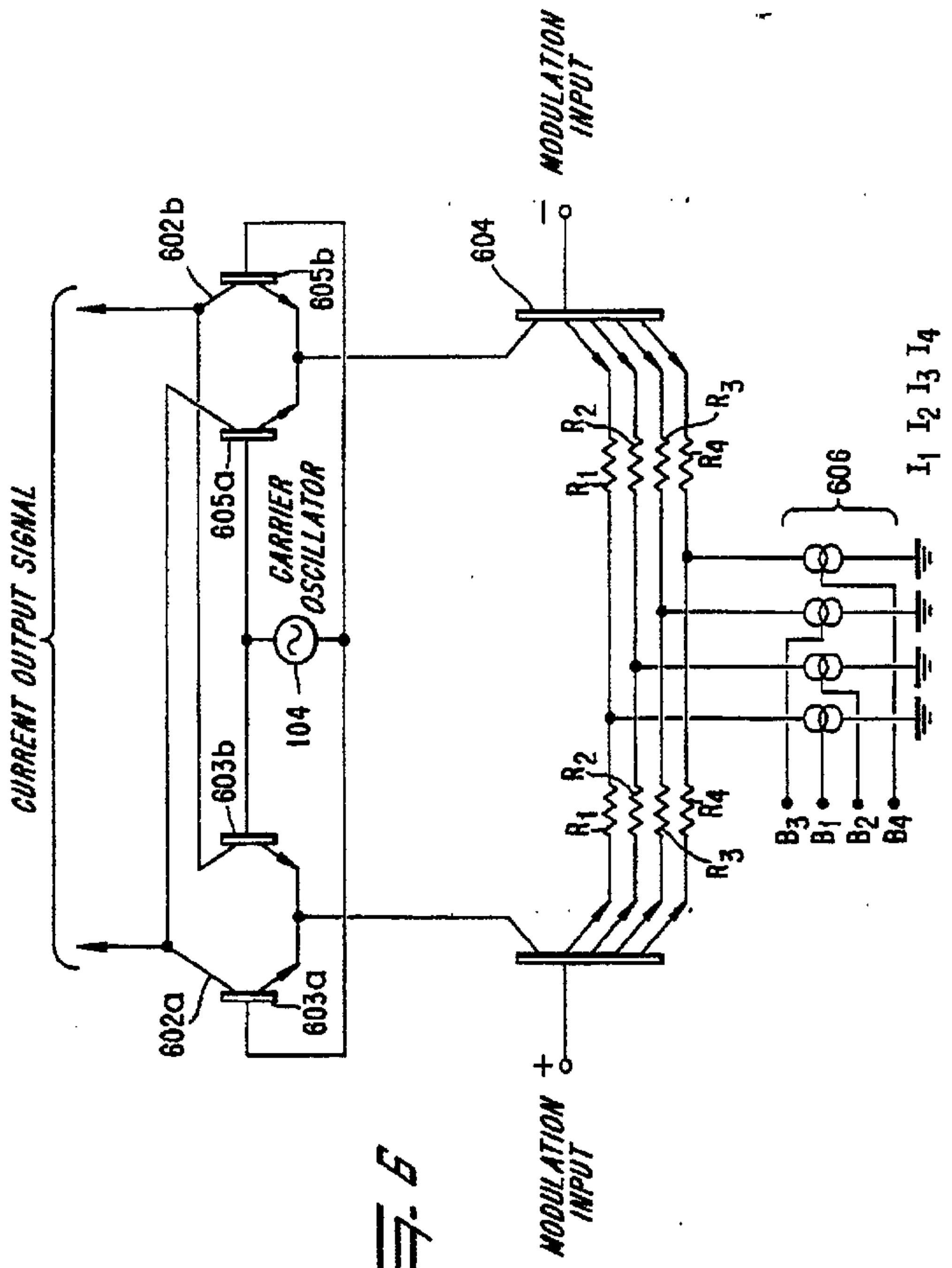

CURRENT OUTPUT SIGNAL
602b
605b
605a
CARRIER OSCILLATOR
104
603b
602a
603a
604
MODULATION INPUT
−
+
MODULATION INPUT
R1
R2
R3
R4
606
I1 I2 I3 I4
B3
B1
B2
B4

FIG. 6

RANDOM ACCESS IN MOBILE RADIO TELEPHONE SYSTEMS

This application is a continuation of application Ser. No. 07/867,149, filed Apr. 10, 1992.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to systems for minimizing interference caused by mobile radio stations initiating and terminating communication with fixed radio stations.

2. Description of Related Art

In cellular radio telephone networks, a mobile subscriber may freely choose when and where to initiate a telephone call. This procedure is known as a random access call set-up. The term random access also applies to the mobile station's first transmission in reply to a call initiated through the mobile station's fixed home base station. In both situations, significant uncertainty exists in determining the mobile's transmission power level at the time of access.

Three principal methods enable a radio telephone system to support multiple, ongoing conversations in a given frequency band. Frequency Division Multiple Access (FDMA) is the traditional method, where every call connection between a mobile and a base station is allocated a unique frequency channel that is occupied continuously until the end of the call. At present, mobile telephone systems are changing from FDMA to time-based methods of sharing communications resources. In Time Division Multiple Access (TDMA), different radio transmitters are allocated short time slots in a periodic cycle in which they transmit bursts of information. In the third approach, Code Division Multiple Access (CDMA), different speech/information signals are transmitted with different spread-spectrum codes so that the coded signals overlap in both time and frequency. The received CDMA signals are decoded by correlation with the code associated with the desired speech/information signal.

In all mobile telephone systems, the physical distance between mobile stations and base stations varies significantly. The signal propagation loss between a radio transmitter and receiver varies as a function of the fourth power of their mutual distance. As a result, large differences may arise in the strength of signals received at the base station from different mobiles. Although conventional cellular radio telephone systems employ a number of techniques to avoid interference between different signals, interference occurs nonetheless as the disparity between the signal strengths from various mobiles increases.

This interference problem is of particular concern in CDMA systems where a mobile signal that is twice as strong as another mobile signal occupies twice the system capacity. Unregulated, it is not uncommon for a strong mobile station to transmit signals at thousands of times the strength of other mobile transmissions. The loss of system capacity to such "strong" mobile stations is unacceptable, and thus power regulation is particularly important in CDMA systems. In commonly assigned U.S. patent application Ser. No. 07/866,554, entitled "Duplex Power Control" filed on Apr. 10, 1992, the present inventor describes a power regulation method and apparatus for a CDMA system. That application is incorporated herein by reference.

In other pending applications by the present inventor, U.S. patent application Ser. No. 07/628,359, filed Dec. 17, 1990, and entitled "CDMA Subtractive Demodulation," now U.S. Pat. No. 5,151,919 and U.S. patent application Ser. No. 07/739,446, filed Aug. 2, 1991, and entitled "CDMA Subtractive Demodulation," now U.S. Pat. No. 5,218,619 incorporated herein by reference, a CDMA subtractive demodulation system is described in which overlapping, coded signals are decoded in the order of strongest to weakest signal strength. After each decoding, the decoded signal is removed or subtracted from the received, composite signal before decoding the next strongest signal. Using such a CDMA subtractive demodulation system, signal strength differences between mobiles become less important and capacity is increased. In other words, the signals having the greatest potential for causing interference, i.e., the strongest signals, are decoded and removed first. In this way, potential sources of interference for weaker signals are significantly reduced.

Even in such a CDMA subtractive demodulation system, however, an interference problem still exists when mobile stations initiate random access call set-ups. Because of the difficulty in gauging an appropriate access power level, there is a risk of at least momentarily interference with ongoing conversations.

Another source of potential interference to ongoing conversations during mobile random accesses is time misalignment of the mobile random access signals relative to the base station's frame timing. For mobile station signals to be received in a correct timeslot (TDMA) or correctly time-aligned to a particular correlating code (CDMA), the mobile station must adjust its access signal transmission timing to account for the round-trip propagation delay between the base and the mobile station. Unfortunately, unless a recent contact has been made with a base station, the mobile station lacks a mechanism for establishing the correct time alignment for a random access.

These problems undermine the efficient operation of current and future cellular systems. Given the frequency with which new calls are placed by mobile telephone subscribers, especially in urban and other congested areas, it is both desirable and necessary for mobiles to make random accesses on the network without generating unnecessary interference. It is also desirable to simply and effectively establish a call connection from mobile to base station that is synchronized with the time-alignment structure of the base station.

SUMMARY OF THE INVENTION

The present invention includes a method for minimizing the interference caused by radio communications initiated between at least one of a plurality of first radio stations and a second radio station. An access message is transmitted from the first radio station at a relatively low power level. A determination is made whether or not the access message has been detected at the second radio station. If the message has not been detected, the access message is retransmitted at an increased level until the message is eventually detected. When the message has been detected, the power level is fixed at the detected level.

The first station may be a mobile radio telephone station and the second station may be a base station. The access message itself includes an access code and an identification code identifying the first station. Each access message is preferably transmitted using spread

spectrum signal coding including orthogonal block error-correction codes. Moreover, each access message is scrambled before transmission using a scrambling code selected from a reserved group of scrambling codes. When the base station has received the access message it acknowledges the receipt and commands the mobile station to discontinue power level increases. The acknowledgment may also include time alignment information that is used by the mobile station in conjunction with the access message transmission power level to determine the time when subsequent mobile communication transmissions should occur.

In one aspect of the invention, a mobile radio station for communicating with at least one other radio station includes means for transmitting an access message to another radio station at a relatively low power level. A detecting means determines if a reply message has been received from the other radio station. The mobile station has means for retransmitting the access message at an increased power level if the reply message is not detected. The retransmitting means increases the power level of the random access transmission in accordance with a ramp function. The mobile station also has means for selecting a scrambling code from a list of available scrambling codes broadcast from the other radio station to generate the random access message. The mobile station additionally has means for adjusting the time of transmission of the access message based on the increased power level.

In another aspect of the invention, a communication system including plural mobile radio telephone stations and at least one fixed base station is disclosed in which each mobile radio station has means for transmitting an access message initially at a relatively low power level; means for regulating the power level of said transmitting means; and control means for controlling said regulating means depending on whether said access message has been detected. The base station includes: means for receiving a composite of signals from said mobile stations; means for detecting mobile access messages; means for decoding detected access messages; and means for transmitting a reply message to the mobile station corresponding to detected access message.

The base station further includes means for ordering received signals that include access messages according to signal strength; means for selectively decoding the strongest signals; and means for removing the decoded signal from the received composite signal. The mobile station includes means for encoding scrambled access messages using bi-orthogonal block codes and means for scrambling access messages using scrambling codes. The base station transmitting means broadcasts a list of reserve scrambling codes separate from scrambling codes used for other radio communications.

The mobile station includes means for adjusting the time of transmission of the access message based on regulated power level and means for detecting time alignment information in the reply message. The base station includes means for determining the difference between the signal strength of the random access message detected in the base station and a predetermined signal strength, and means for determining a time difference between the times the random access was detected and a predetermined time. Finally, the base station detecting means searches for particular access messages at staggered time intervals.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and advantages of the invention will become apparent from reading the following detailed description in conjunction with the drawings, in which:

FIG. 1 is a functional schematic of the transmitter of a mobile station according to the present invention;

FIG. 2 is a functional schematic of a transceiver portion of a base station according to the present invention;

FIG. 3A is an exemplary signal format for a random access message from a mobile station;

FIG. 3B illustrates positional variation of random access message startcode sequences;

FIGS. 4A–4E illustrate the underlying operation of a RAKE receiver;

FIG. 5 is a functional schematic of multi-stage power amplifier in accordance with the present invention; and

FIG. 6 is a functional schematic of a balanced modulator in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

To facilitate an understanding of the invention, an exemplary embodiment in the context of the CDMA subtractive demodulation system such as disclosed in the above-incorporated U.S. patent application Ser. No. 07/628,359, now U.S. Pat. No. 5,151,919 is described. Those skilled in the art will recognize that the present invention may be applied to any radio communications system, including all cellular radio telephone systems, in which it is desirable to minimize interference caused by a random access call attempt between two radio communications devices.

Briefly summarized, in the CDMA subtractive demodulation system, information between plural mobile radio stations and the base station is transmitted in blocks of codewords, e.g., forty-two codewords per block. A convenient signal transmission format is sequences of 128-bit codewords transmitted serially over a radio communications channel. A radio receiver amplifies, filters, samples, and converts the received composite signal, which consists of overlapping communications signals, into digital form for processing. The digitized composite signal is descrambled with a unique scrambling code corresponding to the information signal having the greatest signal strength. The descrambled signal is correlated with "spreading" codes known as orthogonal (or bi-orthogonal) block codes that are associated with the information signals. The 128-bit signal samples are decoded by bi-orthogonal block decoder, by determining which block code has the best correlation to the sample signal, to produce an 8-bit information signal. The decoded information signal, i.e., eight bits, identifies which one of the 128-bit bi-orthogonal codes was transmitted, the latter then being subtracted from the composite signal before attempting to decode the next strongest, coded information signal.

In an exemplary embodiment of the present invention illustrated in FIGS. 1 and 2, a mobile station transmitter 10 includes a radio frequency (RF) power amplifier 100 coupled to a duplex antenna 102. A frequency synthesizer 104 generates the transmission carrier waveform that is modulated with an information signal, e.g., speech, by a quadrature modulator 106. The quadrature modulator 106 may implement a modulation technique such as impulse-excited Quadrature Amplitude Modulation (QAM) in which information bits are modulated alternately on the in-phase (I) channel and the quadra-

ture (Q) channel using the waveforms generated by two low-pass (LP) filters **108**, **110**. A complex modulator **112** calculates impulse response waveforms that correspond to the polarities of received digital information signals and converts those waveforms into analog form. The LP filters **108**, **110** principally remove the digital-to-analog conversion sampling frequency components. Alternatively, the information signal may be mixed initially to a convenient intermediate frequency, and then converted to the higher carrier transmission frequency by heterodyne mixing the modulated intermediate frequency waveform with an offset frequency.

The digital information signals received by the complex modulator **112** are produced by either a block codeword generator and scrambler **114** or a speech encoder **122**. When the mobile station **10** is transmitting a random access message, i.e., before speech communication begins, the message is generated in the control processing unit **166** and input to the block codeword generator and scrambler **114** eight bits at a time. However, when speech transmission commences, the eight bit inputs to block codeword generator and scrambler **114** come from a speech digitizer and encoder **122**. The speech encoder **122** receives a microphone signal from a microphone **124** and outputs eight-bit words. A switch **126** controlled by the control processing unit **116**. For input to the block codeword generator and scrambler **114**, the control processing unit **116** selects either itself for transmission of random access messages or the speech encoder **122** for transmitting conversation. Even after the random access procedure is completed, the control processing unit **116** can operate the switch **126** from time to time to select message transmission and interrupt speech transmission. This is done, for example, for high priority signalling message exchange between the base station **20** and the mobile station **10**, such as Fast Associated Control Channel (FACCH) messages.

In the block codeword generator and scrambler **114**, eight bits of information may be spread using a suitable bi-orthogonal block code to a 128-bit codeword, for example. The 128-bit codeword may then be scrambled by modulo-2 adding a unique scrambling code to the codeword. The information bits and the scrambling code originate from a control processing unit **116** that also selects the carrier frequency to be generated by the frequency synthesizer **104** and transmits a power level command signal to a power level controller **118**.

The power level controller **118** advantageously comprises a combination of attenuators and components for controlling the bias of the power amplifier **100** to achieve the commanded power level when transmitting each codeword. A combination of attenuators and amplifier bias control is useful in achieving a suitably wide transmission power level control range, e.g., 60 dB, and it will be appreciated that a wide variety of combinations are known and the following techniques can be used as desired in the present invention.

Because the power amplifier's final stage might be controllable within only a 20-dB power range, a wide transmission power control range is difficult to achieve by controlling the bias of only one stage of the power amplifier. Accordingly, for a two-stage power amplifier **100**, controlling both stages would yield a 40-dB control range and providing a fixed 20-dB attenuator selectively switched into the output of the power amplifier can achieve the desired 60-dB range. Of course, if bias control of a single amplifier stage is preferred, two independently controllable 20-dB fixed attenuators may be selectively switched into the output, thereby achieving the same 60-dB control range. An example of a multi-stage power amplifier is shown in FIG. **5**.

FIG. **5** is a functional schematic of a multi-stage power amplifier **50** in which modulating in-phase (I) and quadrature (Q) signals are input to a quadrature modulator **106**. The quadrature modulator **106** includes level-switchable balanced modulators controlled by level control bits B_1–B_4 to provide a first 0–20 dB control. A first frequency F_1 providing the carrier frequency is also input to the quadrature modulator **106** from the transmitter frequency synthesizer **104**. The output of the quadrature modulator **106** is input to an upconverter **504**, which is provided with a second frequency F_2 from the transmitter frequency synthesizer **104**. The upconverter **504** heterodyne mixes the modulated signal (which is at a lower frequency for technical convenience) with the higher, fixed second frequency F_2 to translate it to a higher output frequency. Conversely, a downconverter, or super heterodyne mixer, is generally employed in a receiver to convert a high frequency signal received on the antenna to a lower, fixed intermediate frequency at which amplification is more conveniently achieved. In either case, it is advantageous to modulate or demodulate a signal at a lower, fixed frequency and to change the oscillator that drives the mixer to vary the frequency at the antenna.

The output of the converter **504** is input to a bandpass filter **506** and fed to a driver **507**. The gain on the driver **57** is controlled between 0–20 dB by power level controller **118**. The output of the driver **507** is input to a power amplifier **508**, the gain of which is controlled between 0–20 dB by gain control of the power level controller **118**. The output of the final amplifier **508** is input to the antenna **102** for broadcast. This circuit permits a total transmission power control range of 0–60 dB. It will be appreciated that variable attenuators may also be used. Switchable and variable attenuators are commercially available from number of sources, such as Avantek, Inc., Santa Clara, Calif.

A suitable balanced modulator for the quadrature modulator **106** for controlling gain may be provided as shown in FIG. **6**. The circuit of FIG. **6** includes twin balanced modulators **602***a* and **602***b*. Each modulator **602** comprises twin paired transistors **603***a*, **603***b*; **605***a*, **605***b*, the emitters of which are coupled together within each pair. The bases of symmetrically opposing transistors from **603***a*, **605***b*; **603***b*, **605***a* of each pair are coupled together to form,the bridge wherein the local oscillator (transmitter frequency synthesizer **104**) supplying the carrier frequency F_1 is connected in parallel to the bridged circuit. The collectors of the transistors **603**, **605** are cross-linked and form the output of the quadrature modulator **106**. The coupled emitters of each balanced modulator **602** are coupled to the collector of multiple emitter transistors **604**, the bases of which are controlled by the respective modulation inputs. Each of the emitters of each of the multiple emitter transistors **604** are connected together by respective series connected resistor pairs R_1–R_4. The resistor pairs R_1–R_4 are center tapped with switchable current generators **606** (I_1, I_2, I_3, I_4), which are controlled by control bits B_1–B_4. The values of unbypassed emitter resistors R_1–R_4 in each balanced modulator **602** can be selected by selectively energizing the tail current sources **606** associated with each center-tapped emitter resistor

R_1–R_4, thus resulting in a balanced modulator circuit 60 with a binary programmed output level.

Controlling the transmitted power level can also be achieved by numerically scaling the digital I, Q values generated in the complex modulator 112 before they are converted to analog form for the quadrature modulator 106. The control range is somewhat limited, but the gain can be easily and precisely selected, for example in 0.1-dB steps.

FIG. 2 shows an exemplary base station receiver/transmitter 20 for detecting mobile random accesses in a communications environment of overlapping, ongoing radio traffic signals. An antenna 200 receives a composite signal which is amplified by a low-noise, RF amplifier 202. The amplified signal is spectrally shaped by a filter 204, and a dual analog-to-digital converter 206 converts the filtered analog signal into a stream of complex digitized signals having real or in-phase parts (I) and imaginary or quadrature parts (Q). Alternatively, an intermediate frequency mixing stage may precede the amplifier 202 so that amplification and filtering occur at a lower intermediate frequency.

After the frequency demodulation process, the complex, digitized composite signal is processed by a CDMA subtractive signal processor 208. Because the individual signals to be demodulated are each scrambled with a unique scrambling code generated by the mobile station's control processing unit 116, the CDMA signal processor 208 sequentially descrambles the composite signal with each scrambling code in order of greatest to weakest signal strength. The descrambled signal is decoded by correlation with all of the bi-orthogonal codes possibly used for encoding to extract eight bits of information for each 128-bit bi-orthogonal code word. Correlation may be carried out by using for example the Fast Walsh-Hadamard transform processor described in the present inventor's pending U.S. patent application Ser. No. 07/735,805 filed Jul. 25, 1991 and entitled "Fast Walsh Transform Processor". The decoded information bits are transmitted to a base station control processor 212 for further speech/data processing.

By selecting the scrambling codes corresponding to the signals having the greatest signal strength, the base station CDMA processor 208 demodulates the various overlapping signals in order of predicted signal strength from strongest to weakest. A signal strength tracker and sorter 210 predicts the signal strengths from past observations and orders them. Recognizing that power levels change over time, the signal strength tracker and sorter 210 freely reorders the signal decoding sequence to accommodate relative power level changes. Expected signal strength levels may be predicted based on a history of past power levels by extrapolating a next power level using an estimated change of power level.

A random access by a mobile station 10 using low power levels is detected only after stronger signals are decoded. In addition to decoding information or traffic signals, the base station processor 208 searches for and decodes each coded mobile access signal according to its detected power level. Because the mobile access message is transmitted initially at a low power level, it does not interfere with stronger signals being decoded. As soon as an access message is detected, the processor 208 subtracts the access message from the composite signal so that interference with signals decoded later in the signal strength sorted order is minimized.

The power level of the initial random access message from the mobile station 10 is set by the power controller 118 at a low power level. The power controller 118 gradually increases the transmission power in small increments, e.g., 0.1 dB, after each successive codeword is transmitted. These successive power increases continue for the total number of codewords making up the random access message. Preferably, the power level increases according to a ramp function with the ramp slope determining the magnitude of the power increase increment. A ramp function is readily implemented and simplifies the signal strength prediction process of the base station signal tracker and sorter 210. Each successive transmission of the random access message by the mobile station 10 occurs at a power level greater than the preceding access message transmission until the base station 20 detects the access message and transmits a reply message to the mobile station 10. Once that reply message is received and the base station 20 indicates that the mobile power level is in the desired signal strength range, the mobile station 10 fixes its transmitted power at a level specified by the base station 20 in the reply message.

It takes approximately 0.5 milliseconds to serially transmit a single 128-bit codeword. If the mobile increases its transmitted power level by only 0.1 dB per codeword, the power level's rate of change is 200 dB per second, which will be recognized as a high rate of change. Since the typical received power level range for traffic or access signals is on the order of 60 dB, fewer than six hundred codewords need be transmitted before the base station detects the access message. Thus, the worst-case delay in access detection is only about 300 milliseconds. In this way, the present invention allows mobiles to randomly access the cellular network without noticeable delay to the mobile subscriber and without interference to other communications signals.

To simplify the base-station's task of detecting random access messages, the first two codewords out of every 42-codeword message are fixed at a first value, A. Thus, a 42-codeword message begins "AA . . . " For simplicity, message lengths are chosen to be 42 codewords because that is also the length of speech coder frames in the present system. When transmitting speech traffic, the first two codewords also take on the value "AA . . . " to indicate when speech frames are transmitted in full, but may also take on a second value "BB . . . " when it is desired to indicate that the remaining 40 codewords in the following speech frame are not going to be transmitted because the speaker was momentarily silent. This so-called discontinuous transmission or "DTX" is described in commonly assigned U.S. patent application Ser. No. 07/866,555 entitled "Discontinuous CDMA Reception" filed on Apr. 10, 1992 now U.S. Pat. No. 5239,557.

The base station receiver's capability to search for occurrences "AA . . . " or "BB . . . " is therefore, in the preferred system, used for dual purposes of identifying DTXed speech frames as well as random access attempts.

The staggering of the relative position of occurrences of "AA . . . " codewords is linked to the choice of codeword so that, for a particular codeword, the receiver can predict when "AA" should occur, and thus does not have to search for AA on all codewords in every frame.

If the AA sequence is not detected immediately because the first mobile access attempt was made at a low

power level, the next time the base receiver searches for AA the power level will have increased 42×0.1 dB, i.e., 4.2 dB. Although it appears that access attempts could equally well have been increased in power in one 4.2 dB step between attempts, instead of in a smooth ramp-function fashion of 42 smaller steps of 0.1 dB, it is much simpler for the operation of the base station 20 after detection of a random access attempt that the mobile station's power should increase smoothly, as the base station 20 then decodes every codeword and is able more easily to track small changes of power level between codewords.

One objective behind the invention is that the base station 20 should detect random access messages while they are still at a power level too low to interfere with ongoing traffic, and subsequent to detection, to subtract them out as their power rises toward a target level. If a random access was below a detectable level on a previous attempt, it is unlikely that a 4.2 dB increase in signal level before the base station looks for it again would represent a significant interference hazard.

An exemplary random access message sequence is illustrated in FIG. 3A, which shows forty-two codewords in the sequence produced by the control processing unit 116. The first two 128-bit codewords A, A have fixed bit patterns that are recognized by the base station control processor 212 as random access messages; the remaining forty codewords 3, 4, 5, 6, . . . , 42 contain the mobile station's identification code/telephone number in error-correction coded form and communication information.

The codeword A is one of preferably one hundred twenty-eight possible Walsh-Hadamard codewords that are used to indicate random access, and is scrambled with one of a number of reserved scrambling codes unused for traffic. The base station 20 descrambles the received signal with each of the reserved scrambling codes, then correlates for "A" to determine whether a random access has begun. The base station 20 must detect one of the A codewords in order to detect a random access start, and once A is detected, the base station 20 demodulates the remaining forty codewords. The codewords A, A are also used to synchronize communications between the mobile station 10 and base station 20 as described in more detail below.

To avoid overloading the base station 20 by requiring it to look for all the AA sequences for all scrambling codes in the same 128-bit blocks of the 42-codeword sequence, the position of the AA sequence is varied in accordance with the scrambling code used, as shown in FIG. 3B for three scrambling codes. Similar position variations are provided for the remaining scrambling codes. In this way, the base station 20 searches for the codewords A, A at different times for each scrambling code, and so avoids the processing load that would occur if the AA sequences for all scrambling codes had to be detected simultaneously.

In a preferred embodiment of the present invention, each mobile station random access message transmission uses a scrambling code selected from several available scrambling codes that are not presently allocated to traffic communications. These are indicated in a broadcast message transmitted by the base station 20 over a designated CDMA channel on the same frequency. A mobile station 10 attempting an access to the network tunes to that frequency and scans the broadcast list of available scrambling codes. The mobile station 10 selects an available code and transmits a scrambled random access message. The presently unused scrambling codes on a predetermined frequency Fd_1 are identified in a broadcast transmission using one of the CDMA signals overlapping on frequency Fd_1. Preferably this is the strongest of the downlink signals on first frequency Fd_1 so it can be decoded by any mobile station 10. This effectively acts as a "calling channel" in which the signal serves as a pilot signal to assist the mobile demodulator. The aim is that each frequency channel is self-supporting as far as broadcasting information is concerned. Once the access is detected and recognized as an access code, the base station control processor 212 removes that code from the broadcast list and proceeds to decode the access message as described previously. Alternatively, the access codes currently in use can be broadcast as a list so that the mobile station 10 can select from those remaining on an internally stored list.

Random access transmissions start at a specific boundary (i.e., the start of a 42-codeword message block "AA . . . ") that divides a mobile access message into a specific number of codewords, e.g., 42. Each two word scrambled start code AA is staggered in time, as explained above, to distribute as evenly as possible the base station's task of searching for random access messages. As a result, the control processor 212 only needs to search at one time interval for a fraction of the possible random access scrambling codes for each block decoding operation. The CDMA signal processor 208 also searches for random accesses using the scrambling codes of mobile stations 20 in neighboring cells that are received at a signal strength strong enough to produce interference.

Time-alignment information is provided by the base station transmitter 214 to a transmit timing controller 120 from the processing unit 116. In response to detecting a random access message, the base station transmitter 214 transmits reply information to the mobile processing unit 116, such as the timing difference between the time at which the mobile access transmission was received by the base station 20 and a preset, target timing value. Other information includes the difference between the signal strength of the detected random access message and a predetermined signal strength.

The mobile station 10, even before random access, listens to the calling channel (i.e., the strongest of the CDMA signals overlapping on the same frequency). It locks to this signal and thus has established timing synchronization with the base station 20 at the 42-codeword frame level as well as at the spreading code chip level.

The mobile station 10 has from the beginning been listening to the calling channel broadcast from the base station 20. The signal structure on the calling channel also consists of 42-codeword messages beginning with "AA . . . ". The mobile thus knows the time of occurrence of AA on the downlink calling channel, from which the time-stagger of all other codewords is defined. For example, if we use the notation that the calling channel employs scrambling code Co, and traffic channels may use scrambling codes C1, C2, etc., then the time of occurrence of AA in the signal scrambled with code C1 will be two codewords after the time of occurrence on the calling channel; likewise, the time of occurrence of AA in the signal scrambled with codeword C2 will be four codewords after AA on the calling channel, and so forth.

Calling channel:	...AA..................AA......
Signal using C1:	......AA....................AA......
Signal using C2:	.......AA....................AA.....

It is necessary to obtain synchronization to a finer resolution than merely determining the 0.5 mS slot in which the first A might occur. Each codeword such as A in fact consists of 128 "chips". "Chips" in CDMA terminology is really the same as "bits", and is used to signify that CDMA in fact transmits many such chips to convey each bit of information.

To correctly descramble a codeword and perform a 128-bit correlation it is necessary to align the descrambling code with the received signal to an accuracy of one chip. This is what is meant by having achieved synchronization at the chip level as well as at the frame structure level. Synchronizing to the frame structure means finding at which one of 42 possible codeword positions in the frame structure the AA sequence is expected; synchronization to chip resolution means determining to which of 128 possible chip positions within that codeword period the descrambling code must be aligned. This is actually done by trying several positions and analyzing how much correlation is found on each position.

The above refers to operation of the mobile receiver; however, the timing so found is conveyed from the mobile receiver to the mobile transmitter parts such as block code generator and scrambler 114 so that they produce signals with a frame, codeword and chip alignment that is related to that received from the base station 20. In other words, the base station 20 is the master timing reference to which all mobile stations 10 synchronize and thus are able to transmit signals with a determined time relation.

Due to unequal distances from different mobile stations 10 to the same base station 20, however, even if mobile stations 10 transmitted signals aligned at the same instant in time, they would not be received aligned at the base station 20. Therefore the transmit code generator 114 is told by the control processing unit 116 to produce transmit signals a little earlier to account for the loop propagation delay from base to mobile station 10 and back again. The exact amount of timing advance needed may be determined by the base receiver measuring the time alignment of the received mobile signals, determining how early or late they are with respect to a predetermined position, and then transmitting a message to the mobile station 20 giving the amount (e.g., number of chips + or −) that the mobile station 10 shall adjust its time advance.

When the mobile station 10 makes a first transmission to the base station 20 during random access, it relates its transmit frame, word and chip timing to the timing it has received. Thus, the base station 20, by comparing its timing on the outgoing calling channel with the timing of the received mobile signal can determine the round trip delay. The base station 20 determines how early or late the mobile timing is with respect to a predetermined time alignment desired for all mobile signals to be received. It can then, in the reply confirming reception of the random access transmission, send information to the mobile station 10 enabling the mobile station 10 to adjust its transmit timing to the right position. This information could either be an absolute timing advance for the mobile station 10 to use (in which case the base station 20 needs to know what timing advance the mobile station 10 was already using), or the amount of adjustment or Δ the base station 20 wants the mobile station 10 to apply (in which case the base station 20 does not need to know the amount of timing advance the mobile station 10 is already using).

The choice between these is not critical to the invention, and is a matter of system philosophy. At present the preferred approach is that the mobile station 10 includes, in its random access transmission, not only its mobile ID but also details of the power level and timing advance that the transmission used. Then the base station 20 additionally adjusts the signal and sends the absolute values back to the mobile station 10. The mobile station 10 then continues to ramp its power and its timing at the same, gentle rate until it hits the target values received from the base station 20 most recently.

As an example of a mobile random access message, 40 codewords of data present in the 42-word frame and a rate ½ error correction code, yield 20 bytes of information after decoding. These bytes can be deployed in the random access message as follows:

Message type:	1 byte
Message number:	1 byte
Mobile Identification number:	4 bytes
Power level in use to nearest 0.5db:	1 byte
Timing advance in use to nearest ¼ chip:	1 byte
Called number (mobile originated call):	8 bytes
Spare bytes for future use:	2 bytes
Cyclic redundancy check code:	2 bytes
Total	20 bytes

The reply from the base station to the mobile upon detection of first transmission can be of similar form:

Message type:	1 byte
Message number:	1 byte
Mobile Identification number:	4 bytes
Power level in use to nearest 0.5db:	1 byte
Timing advance in use to nearest ¼ chip:	1 byte
Spare bytes for future use:	11 bytes
Cyclic redundancy check code:	2 bytes
Total	20 bytes

There are 42 codewords in a frame, the frame being the coarsest unit of timing resolution. Each codeword contains 128 chips, codewords and chips being finer units of timing resolution, but in addition, a chip, which in the preferred system is about 4 microseconds long is generated by dividing an even higher frequency clock (i.e., producing pulses even shorter than 4 uS) by some integer. For example, in one implementation, a 12.8 MHz clock is divided by 48 to produce pulses of one chip duration. Each pulse of the 12.8 MHz clock is thus of 1/48th of a chip duration, so the present system can fine-tune any timing adjustment to fractions of a chip resolution if need be. In practice, we do so also as it is desirable not to alter timing in large steps for the same reason as it is not desirable to alter power level in large steps, but to ramp smoothly in smaller steps between one value and the next. It is only necessary to specify the target or destination value to an accuracy or resolution of ¼ of a chip period, however. For example, if it is detected by the base station receiver that a particular mobile signal is arriving between 0 and 1 chip earlier than the others, on average say 0.71 chips, this can be rounded up to ¾ of a chip and the timing advance byte value would be changed by 3 and conveyed to the mo-

bile in a timing adjustment message. Over the next few codewords, the mobile would ramp its timing in 1/48th of a chip steps per codeword, taking in total 36 codewords or around 18 mS to make the adjustment of $\frac{3}{4}$ chip. This is fast enough for practical purposes.

In the above format, the "spare bytes" may be used by the base station 20 to command the mobile station 10 to switch to a less heavily loaded frequency channel.

An example of the use of the above message format assumes a mobile station 10 begins a random access transmission at the lowest power level. If a signal at this level has a chance of establishing communication, the mobile station 10 cannot be very far away from the base station 20, and therefore zero timing advance is used. According the first message from the mobile station 10 contains:

Power byte=0;

Timing advance=0.

The mobile station 10 continues to increase its power by approximately 0.1 dB per codeword so that the first repeat message will begin at about 4.1 dB higher power than the first message. With 0.5 dB quantizing of the power byte, the value included in the message would be 9. No change to the timing advance would be needed until the power levels reached much higher values without an acknowledgement from the base station 20, indicating that the mobile station 10 is at a significant distance. The maximum distance normally envisaged for cellular communications is 30 Km, for which 200 uS relative timing advance is needed to compensate for the round-trip delay. Thus, at maximum power, the timing byte included in the random access repeat message would indicate an advance in the 200 uS range. Because other reasons than distance can require the mobile station 10 to use higher powers, for example local shadowing, it can be desirable not to employ the maximum time advance but about 100 uS less, which leaves 100 uS to be coped with by the base station's capacity to accept delayed signals up to a certain maximum delay of, for example, 32 chip periods, a chip being for example 4 uS long. With these example figures, $\frac{1}{4}$ chip is 1 uS long, and the timing byte value represents microseconds of timing advance currently employed by the mobile station 20.

If the mobile station signal was first detected by the base station 20 at the seventh attempt when it had reached about half the maximum power (in dBs) (i.e., a power byte value of 60), the mobile station 10 employed a timing advance byte value of 40, for example. The base station 20 detected the mobile station 10 while its signal was still quite weak and it is desirable for the mobile station 10 to continue increasing power by, for example 16 dB, to bring it into the target range. Moreover, the mobile signal was detected to be, for example, 20 uS late compared with the base station's preferred timing window. The base station 20 acknowledgement message would thus contain the values:

Power to use byte=60+16/0.5=92.

Timing to use byte=40+20=60.

The mobile station 10, upon receipt of this message, would continue to ramp its power and timing until the commanded values are reached.

Due to processing delay in the base station 20 and the mobile station 10, or failure due to temporary radio noise to detect the first acknowledgement message, it is probable that the mobile station 10 will make at least one more attempt (e.g., power=68, timing=42) before an acknowledgement message is received. This will also be detected by the base station 20 at a higher power level that is now within 12 dB of the target range and within 18 uS of the desired optimum timing. The base station 20 thus sends another acknowledgement message with the values:

Power to use byte=68+12/0.5=92

Timing to use byte=42+18=60

The base station 20 thus gives the mobile station 10 consistent instructions, so that the mobile station 10 will eventually adopt the desired parameters.

Based on this information, the processing unit 116 directs the timing controller 120 to advance the timing of the transmission of the mobile access message by a timing advance factor to compensate for the propagation delay caused by the distance between the mobile station 10 and the base station 20. The access transmission timing factor may be zero and then increase to effect earlier transmission times as the access message transmission power level increases. The greater the power level required, the greater the distance between the mobile station 10 and the base station 20, and the earlier the access message must be sent to be properly time aligned. It is preferable for the base station transmitter 214 to broadcast information that will allow the mobile station control unit 116 to more accurately adapt the timing controller 120 to the time advance/power level increase relationship to the propagation law pertaining to that base station's cell, in the manner described above. Such information includes the base transmitter's effective radiated power and the radial propagation loss profile in different directions.

An issue that is also solved by the message exchange between mobile station 10 and base station 20 is to ensure that the mobile station 10 can receive the base station transmissions using the traffic scrambling code rather than the calling channel code, and to confirm this to the base station 20 so that the base station 20 can cease transmissions on the calling channel in order to save calling channel capacity.

Moreover, the other mobile stations 10 in the cell could be disturbed by the sudden appearance of a new base station transmission at arbitrary power level. The same random access issue of avoiding interference by sudden appearance of a new code therefore has to be solved in the reverse direction.

The preferred means for the base station 20 to begin transmission on a previously unused code is to begin at a power level lower than any of the ongoing signals and to ramp it up slowly, just like the mobile station 10, at the approximate rate of 0.1 dB per 0.5 mS codeword. At the same time, the code is removed from the list of unallocated codes, or rather, added to the list of used codes broadcast from the base station 20.

The format for the list of codes in use broadcast for the base station 20 is:

Number of codes in use	(1 to 24) 5 bits
Code number of strongest signal	(1 of 31) 5 bits
Code number of 2nd strongest signal	(1 of 30) 5 bits

-continued

.	.
.	.
Code number of 15th strongest	(1 of 17) 5 bits
Code number of 16th strongest	(1 of 16) 4 bits
Code number of 23rd strongest	(1 of 9) 4 bits
Code number of 24th strongest	(1 of 8) 3 bits
Total bits 5 + 8 × 5 + 8 × 4 + 4 × 3 + 2 × 2 + 1 = 115 bits	

Therefore, within a 20-byte data message, the bytes can be allocated to the above broadcast message as follows:

Message type:	1 byte
Code order as above:	15 bytes
Spare for future use:	2 bytes
Cyclic redundancy check code:	2 bytes
Total:	20 bytes

This message may be read by mobile stations 10, other than that attempting random access, to warn them of the imminent commencement of transmission with a previously idle code. It is also readable by an idle mobile station 10 and may be used to determine the traffic loading on each frequency channel it scans, thus enabling it to choose to make a random access on the most lightly loaded frequency channel.

Because the power level with which the base station 20 begins transmission is unlikely to be more than 35 dB below the strongest signal, it takes only 360 codewords (180 mS) to increase from weakest to strongest position at the rate of 0.1 dB per codeword. During this time, in the case of a mobile station 10 originated call, the base station 20 can already pass the called number to the land network so that the delay in the land network making connection to the called subscriber is in parallel with the completion of random access and not in series with it. In other words, making the land-line connection occurs simultaneously with the completion of random access rather than sequentially.

During this period, the mobile station 10 continues to demodulate the common calling channel as well as listening for the base signal to appear using the mobile's own scrambling code. The base station 20 transmits the same data on both the calling channel and the mobile's code, thus facilitating detection of the signal by the intended mobile station 10 as well as subtraction of the signal by other mobile stations 10. When the mobile station 10 has successfully detected the signal using its own scrambling code, it acknowledges this fact to the base station 20 by use of an uplink acknowledgement message format as follows:

Message type:	1 byte = "acknowledge"
Message number:	1 byte
Mobile Identification number	4 bytes
Message number of base message acknowledged:	1 byte
Signal strength ordering of detected own code:	1 byte
Other base calling channel strengths:	8 bytes
Spare bytes for future use:	2 bytes
Cyclic redundancy check code:	2 bytes
TOTAL	20 bytes

The mobile station 10 repeats this message with incrementing message numbers until the base station 20 ceases to transmit the power and time alignment message type and sends a new message type or traffic. The progress of the base/mobile interchange thus achieves the objective of the invention: the establishment of a duplex, base-mobile link on a unique channel. Once the base station 20 is satisfied with the power level and time-alignment, it sends a "traffic channel allocation" message to the mobile station 10. The traffic channel allocation message indicates to the mobile station 10 that the random access has been accomplished and that the mobile station 10 may proceed to the next stage of call set-up. For mobile initiated call set-ups, the mobile station 10 transmits the telephone number of the party being called. When the traffic channel allocation message is sent to the mobile station 10, the mobile station 10 switches to the code/frequency parameters indicated in the message. Thus, a closed-loop control of timing and power level is formed between the mobile station 10 and the base station 20. Preferably, the power level control loop functions in accordance with the system described in a pending application "Duplex Power Control," U.S. patent application Ser. No. 07/866,554, filed on Apr. 10, 1992, and incorporated above by reference. More generally, however, the traffic channel allocation message may include a command to change a CDMA code from a random access code which may be common to all mobiles attempting random accesses to an assigned code for traffic communication. In addition, the traffic channel allocation message could include a command to change to another frequency. The procedure beyond this point is termed the completion of "call set-up" and could include other message exchanges for the purposes of authenticating the mobile station 10 in the accessed network, or vice versa. In addition, the transmission power levels that the mobile station 10 and base station 20 adopt beyond the cessation of power and time alignment messages may be controlled using the technique of "Duplex Power Control" disclosed in a separate application, Ser. No. 07/866,554 mentioned above.

To compensate for time-dispersion and echoes on the radio channel as well as uncertainty in the time-of-arrival of random access messages, the CDMA signal processor 208 processes several different shifts of the received, digitized signal samples and combines the decoded results of each shift in a conventional RAKE detector receiver.

A RAKE receiver anticipates that the signal has come through a channel that adds delayed echoes. FIG. 4A shows that a desired component/shift of the originally transmitted signal appears aligned at a distinct point in time To at amplitude Co. If on the other hand an echo is added over the transmission path causing the desired signal component also to appear at T1 with amplitude C1, then the signals appear as represented in FIG. 4B. In general, the RAKE receiver anticipates a number of echoes to be received at To, To+dT, To+2dT, To+3dT . . . and with respect amplitudes Co, C1, C2, C3, etc., as shown in FIG. 4C.

The positions and amplitudes expected are predicted from past history and a number of RAKE taps placed at the expected positions in a delay register to collect the echoes, which are then added with appropriate weights.

Thus, the RAKE receiver is able to search for a signal at an earliest possible time of arrival To by placing one RAKE tap at To; the receiver is also able to search for the signal arriving at a delayed time To+dT by placing a single RAKE tap at To+dT, and so on. The

total possible spread of the taps on the delay register determines the total amount of uncertainty in the time of arrival that can be searched. In the preferred system, up to 32 chips of time delay can be searched, corresponding to up to around 128 uS time delay.

When taps containing significant energy have been identified, detection of the signal proceeds by setting several RAKE taps to collect energy from those time shifts and add the taps with suitable weighting to maximize the signal to noise and interference ratio. In the preferred system, the total spread of taps that are combined in this way is 8 chips; that is, the taps that contain significant energy can be delayed by up to 32 chips, but all those selected to be added for detection have to lie within an 8-chip window somewhere in that 32 chip range. This is more a practical simplification that is found to be permissible without undue loss of performance, than a matter of principle. To illustrate how manipulating the RAKE taps adapts the receiver to accept signals that are more or less delayed, FIG. 4D shows taps 4, 5, 6 and 7 being non-zero while taps 0, 1, 2 and 3 are given zero weight. This arrangement would combine energy received starting at the first time position T4, and decode it. In FIG. 4E, taps 4, 5, 6 and 7 are zero but taps 0, 1, 2 and 3 have the values that taps 4, 5, 6 and 7 had in FIG. 4D. The RAKE receiver is thus adapted to receive precisely the same signal as in the first case, just when an earlier time of arrival T0 instead of T4. Thus, by adjusting the positions and relative values of the tap weights, the RAKE receiver is able to receive signals with more or less propagation delay.

A similar issue of interference avoidance may exist when a call is terminated. There is less of a danger of causing interference due to the sudden disappearance of a signal than due to the sudden appearance of a new signal, but even the residual danger may be eliminated by adoption of a soft termination procedure as follows:

After the base station 20 or mobile station 10 has transmitted the last traffic frame, it goes into the discontinuous transmission mode more fully described in a U.S. patent application Ser. No. 07/866,555, entitled "Discontinuous CDMA Reception" filed on Apr. 10, 1992 now U.S. Pat. No. 5,239,557. This removes 40 out of the 42 codewords transmitted per frame in a manner which other receivers are aware of, leaving only the two codewords out of the 42 designated as "DTX FLAGS" being transmitted. These are transmitted at gradually diminishing power levels equivalent to −4 dB per 42-word frame, approximately. After 10 frames the signal level has been reduced 40 dB and the transmission can now be terminated, this having taken only about 200 mS. The base station 20 then removes the access code used from the broadcast list of codes in use, so that another mobile station 10 is free to start a random access on that code.

While particular embodiments of the present invention have been described and illustrated, it should be understood that the invention is not limited thereto since modifications may be made by persons skilled in the art. The present application contemplates any and all modifications that fall within the spirit and scope of the underlying invention disclosed and claimed herein.

What is claimed is:

1. A method for minimizing co-channel interference caused by radio communications initiated between at least one of a plurality of first radio stations and a second radio station, comprising the steps of:

communicating from said at least one of a plurality of first of radio stations to said second radio station using the same radio frequency subject to co-channel interference;

transmitting from said at least one first radio station an access message at a relatively low power level;

determining whether said access message has been detected by said second radio station;

retransmitting said access message at an increased power level until said access message is detected; and

upon detecting said access message, transmitting power setting information including a specific power increase quantity for said first station from said second station.

2. A method according to claim 1 wherein said first station is a mobile radio telephone and said second station is a base station.

3. A method according to claim 1 wherein said access message includes an access code and an identification code of said first station.

4. A method according to claim 1 wherein said access message is transmitted using spread-spectrum signal coding.

5. A method according to claim 4 wherein said access message includes orthogonal block error-correction codes.

6. A method according to claim 4 wherein said transmitting step includes:

scrambling said access message using a scrambling code selected from a reserved group of scrambling codes.

7. A method according to claim 6 wherein said scrambling codes are identifiable from information broadcast on a common calling channel.

8. A method according to claim 1 further comprising: acknowledging at said second station reception of said access message.

9. A method according to claim 8 wherein said acknowledging step includes commanding said first station to discontinue after a specified delay power level increases.

10. A method according to claim 1 wherein a time of transmission of said access message is based on a power level currently in use.

11. A method according to claim 8 wherein acknowledging step includes transmitting time alignment information.

12. A method according to claim 8 wherein acknowledging step includes transmitting power adjustment information.

13. A method according to claim 1 further comprising the step of terminating said radio communication including gradually diminishing said power level and terminating said communication when said power level has diminished by a predetermined extent.

14. A method according to claim 13 wherein said terminating step includes entering a discontinuous transmission mode.

15. A mobile radio station for communicating with at least one other radio station, comprising:

communicating from said mobile radio station to said at least one other radio station using the same radio frequency subject to co-channel interference;

means for transmitting from said mobile radio station to said at least one other radio station a random access message at a relatively low power level;

means for detecting an reply message from said at least one other radio station; and

means for commanding said transmitting means to retransmit said random access message at an increased power level if said reply message has not been detected to include an acknowledgement supplying power setting information comprising a specific power increase quantity.

16. The mobile station according to claim 15, wherein said retransmission commanding means increases said power level according to a ramp function.

17. The mobile station according to claim 15, wherein said transmitting means includes:

means for selecting a scrambling code from a list of scrambling codes broadcast from said other radio station to generate said random access message.

18. The mobile station according to claim 15, further comprising:

means for adjusting the time of retransmission of said access message based on said increased power level.

19. A communications system with minimized co-channel interference, comprising:

plural mobile radiotelephone stations, each mobile station including:

means for transmitting an access message initially at a relatively low power level;

means for regulating the power level of said transmitting means; and

control means for controlling said regulating means depending on whether said access message has been detected;

at least one base station including:

means for receiving a composite of overlapping signals transmitted from said mobile stations on the same frequency channel subject to co-channel interference;

means for detecting said access messages; and

means for transmitting a reply message including power setting information comprising a specific power increase quantity to the mobile station corresponding to said detected access message.

20. The system according to claim 19, wherein said base station further comprises:

means for ordering received signals including said access messages according to signal strength;

means for selectively decoding the strongest signal; and

means for removing said decoded signal from said received composite signal.

21. The system according to claim 20, wherein each mobile station includes:

means for encoding access messages using orthogonal or bi-orthogonal codes to produce coded access messages; and

means for scrambling said coded access messages using unique scrambling codes.

22. The system according to claim 21, wherein said scrambling codes are reserved for random access messages.

23. The system according to claim 22, wherein said base station transmitting means broadcasts a list of said reserved scrambling codes that enables the mobile station to determine an available access code.

24. The system according to claim 22, wherein said base station transmitting means broadcasts a list of said reserved scrambling codes separate from scrambling codes used for other radio communications.

25. The system according to claim 22, wherein said base station transmitting means broadcasts a list of said reserved scrambling codes used for other radio communications.

26. The system according to claim 19, wherein said access message includes a mobile station identification code and a random access code.

27. The system according to claim 19, wherein each mobile station includes means for adjusting the time of transmission of said access message based on said regulated power level; and means for detecting time alignment information in said reply message.

28. The system according to claim 27, wherein said base station includes means for determining the difference between the signal strength of said random access message detected at said base station and a predetermined signal strength.

29. The system according to claim 28, wherein said determining means determines a time difference between the time said random access was detected and a predetermined time.

30. The system according to claim 19, wherein said receiving means includes means for correlating with a predetermined signal spreading code associated with said access messages.

31. The system according to claim 30, wherein said detecting means is a RAKE detector.

32. The system according to claim 19, wherein said base station detecting means searches for particular access messages at staggered time intervals.

33. A method for establishing radio communications between at least one of a plurality of first radio stations and at least one second radio station, comprising the steps of:

selecting, by one of said first stations, a lightly loaded channel subject to co-channel interference of said at least one of said second stations; and,

following a random access procedure including

selecting, by said first station, a scrambling code identified from a list of codes broadcast by said second station;

transmitting, by said first station, a call initiation message including said selected code at a relatively low power level; and

gradually increasing, by said first station, said power level of said transmitted message until an acknowledgement message is received from said second station, said acknowledgement message including a specific power increase quantity.

34. A method according to claim 33, wherein said channel selection step includes

receiving and decoding signals on channels from one or more of said second radio stations at various radio frequencies;

determining the load on each received channel; and

selecting a lightly loaded channel with clear reception qualities.

35. A method according to claim 33, wherein said random access procedure further includes

starting said random access procedure upon receipt of an call initiation signal transmitted by one of said first station and said second station.

36. A method according to claim 35, wherein said random access procedure further includes

determining, by said second station, whether a code from said list of codes is being transmitted by a first station;

transmitting, by said second station, an acknowledgement message upon receipt and decoding of said transmitted message using said selected code;

transmitting, by said first station, a second message to said second station upon detection of said acknowledgement message; and

ceasing transmission of said acknowledgement message by said second station upon receipt and decoding of said second message.

37. A method according to claim 33, wherein said acknowledgement message from said second station is transmitted on a common calling channel and includes timing adjustment information for timing further transmissions from said first station.

38. A method according to claim 36, wherein said second station transmits said acknowledgement message initially at a low power level and gradually increases said power level until receipt of said second message.

39. A method according to claim 36, wherein said second message includes signal strength information.

40. A method according to claim 35, wherein said first station receives said acknowledgement message

from both common calling channel and said selected channel.

41. A method according to claim 33 further comprising the step of terminating said communication including gradually diminishing said power level of said transmitted message and terminating said communication when said power level is diminished by a predetermined extent.

42. A method for minimizing interference caused by termination of radio communications between a first radio station and a second radio station, comprising the steps of:

entering a call termination mode after a last communication segment;

gradually diminishing a transmission power level; and

terminating transmission when said power level has diminished by a predetermined extent.

43. A method according to claim 42, wherein said termination mode is a discontinuous transmission mode in which frames of data are reduced to no more than two flags.

* * * * *

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United States Patent [19]

Sammarco

[11] Patent Number: 5,551,073

[45] Date of Patent: Aug. 27, 1996

[54] AUTHENTICATION KEY ENTRY IN CELLULAR RADIO SYSTEM

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[73] Assignee: Ericsson Inc., Research Triangle Park, N.C.

[21] Appl. No.: 23,345

[22] Filed: Feb. 25, 1993

[51] Int. Cl.[6] H04B 1/38

[52] U.S. Cl. 455/89; 455/54.1; 379/58; 379/62; 380/23; 340/825.34

[58] Field of Search 380/23, 25, 21; 455/54.1, 89, 56.1, 33.1; 379/58, 62, 63, 59; 340/825.31, 825.34, 825.22

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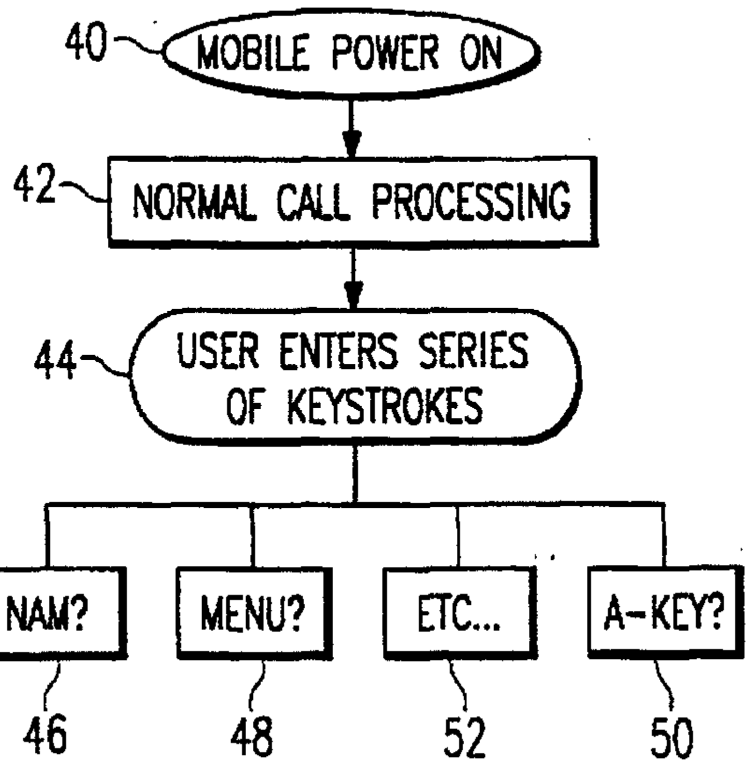
Primary Examiner—Reinhard J. Eisenzopf
Assistant Examiner—Lee Nguyen
Attorney, Agent, or Firm—Robert A. Samra

[57] ABSTRACT

A mobile station is disclosed which may be operated in both a set-up programming mode and in an authentication key programming mode. The authentication key programming mode may be invoked through a series of keystrokes on a keypad in the mobile station. The mobile station allows the entry of a separate authentication key for each mobile station identification number stored in memory. The mobile station also checks the accuracy of the entered authentication key and alerts the user as to whether the entered authentication key is valid or invalid.

15 Claims, 2 Drawing Sheets



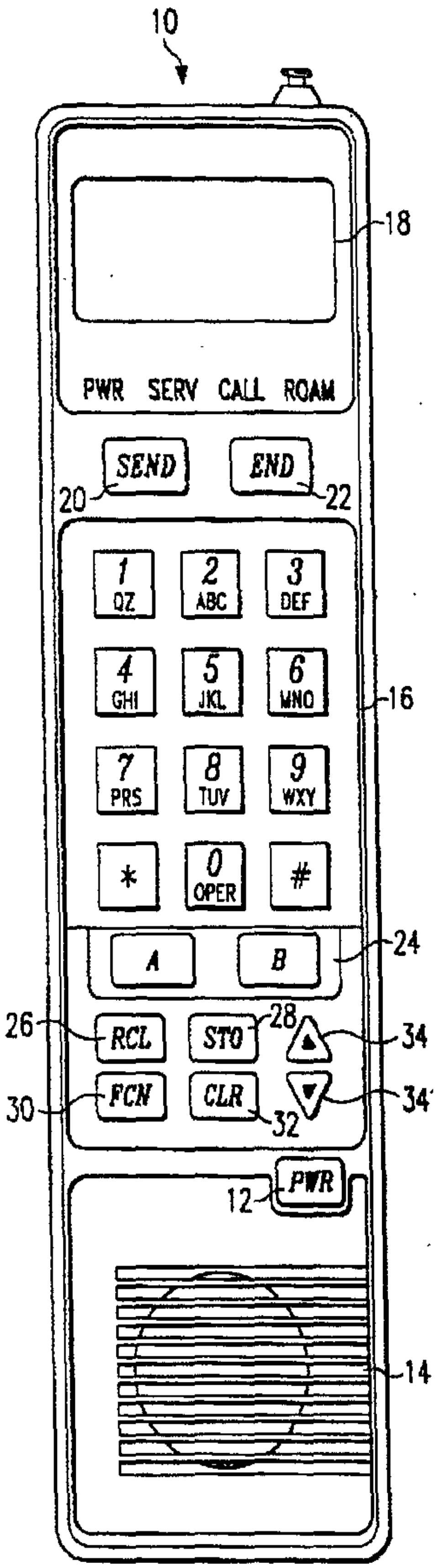

10
18
PWR SERV CALL ROAM
SEND
END
20
22
1 QZ
2 ABC
3 DEF
4 GHI
5 JKL
6 MNO
7 PRS
8 TUV
9 WXY
*
0 OPER
#
16
A
B
24
26
RCL
STO
28
34
30
FCN
CLR
32
34'
12
PWR
14

FIG. 1

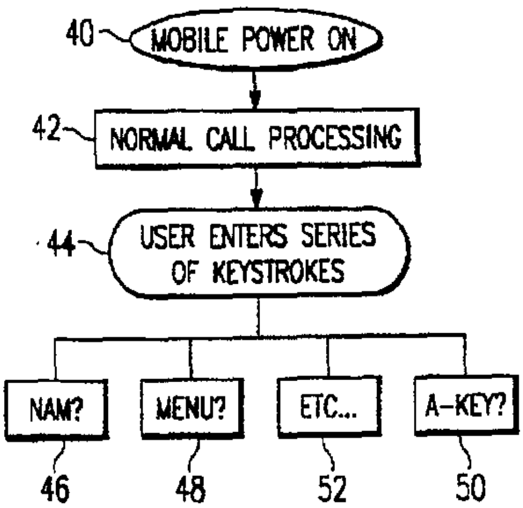

40
MOBILE POWER ON
42
NORMAL CALL PROCESSING
44
USER ENTERS SERIES OF KEYSTROKES
NAM?
MENU?
ETC...
A-KEY?
46
48
52
50

FIG. 2

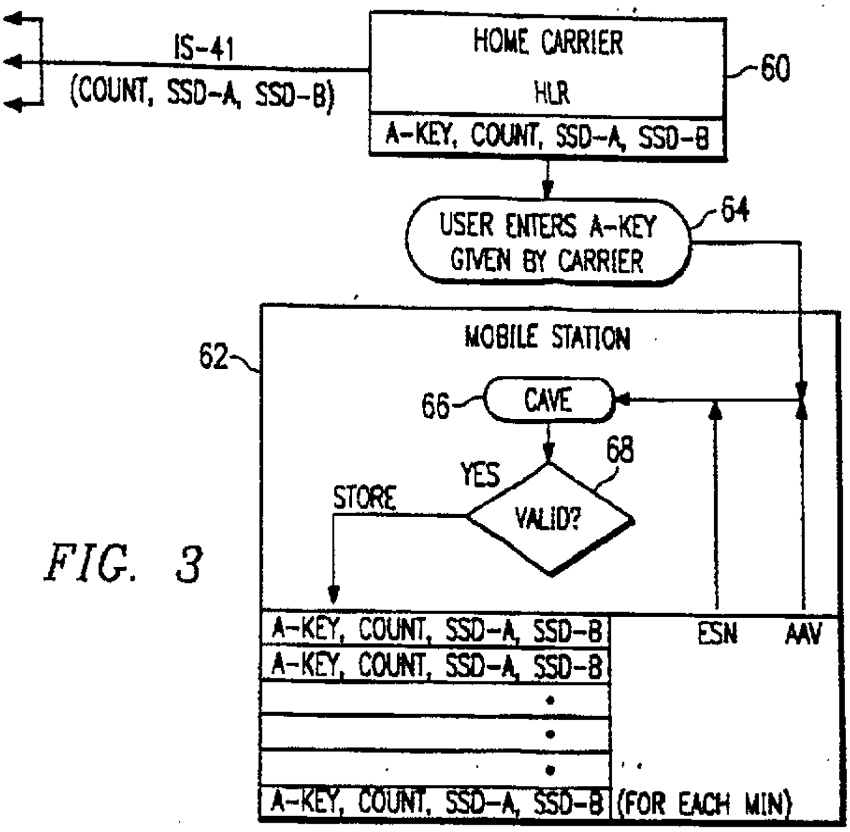

IS-41
(COUNT, SSD-A, SSD-B)
HOME CARRIER
HLR
A-KEY, COUNT, SSD-A, SSD-B
60
USER ENTERS A-KEY GIVEN BY CARRIER
64
MOBILE STATION
62
66
CAVE
68
YES
STORE
VALID?
A-KEY, COUNT, SSD-A, SSD-B
A-KEY, COUNT, SSD-A, SSD-B
A-KEY, COUNT, SSD-A, SSD-B
ESN
AAV
(FOR EACH MIN)

FIG. 3

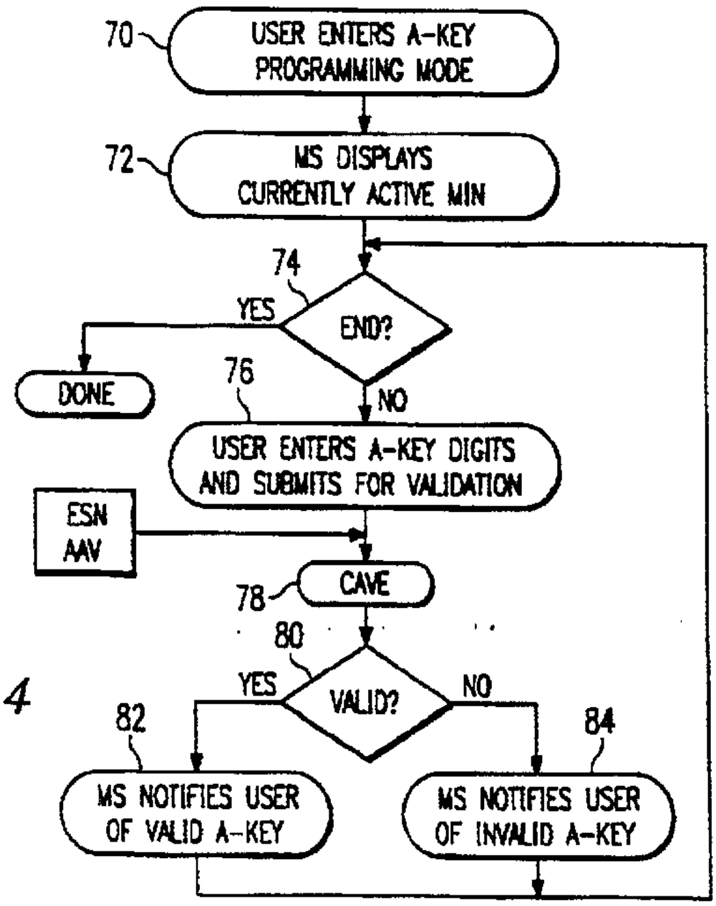

70
USER ENTERS A-KEY PROGRAMMING MODE
72
MS DISPLAYS CURRENTLY ACTIVE MIN
74
YES
END?
DONE
76
NO
USER ENTERS A-KEY DIGITS AND SUBMITS FOR VALIDATION
ESN
AAV
78
CAVE
80
YES
VALID?
NO
82
84
MS NOTIFIES USER OF VALID A-KEY
MS NOTIFIES USER OF INVALID A-KEY

FIG. 4

AUTHENTICATION KEY ENTRY IN CELLULAR RADIO SYSTEM

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to wireless communication systems, and more particularly, to a method and apparatus for entering an authentication key which is used to authenticate mobile stations in a cellular radio system.

2. History of the Prior Art

Cellular mobile telephony is one of the fastest growing segments in the worldwide telecommunications market. Between 1984 and 1992, for example, the number of mobile telephone subscribers in the United States grew from around 25,000 to over 10 million. It is estimated that the number of subscribers will rise to nearly 22 million by year end 1995 and to 90 million by the year 2000.

Cellular telephone service operates much like the fixed, wireline telephone service in homes and offices, except that radio frequencies rather than telephone wires are used to connect telephone calls to and from the mobile subscribers. Each mobile subscriber is assigned a private (10 digit) directory telephone number and is billed based on the amount of "airtime" he or she spends talking on the cellular telephone each month. Many of the service features available to landline telephone users, e.g., call waiting, call forwarding, three-way calling, etc., are also generally available to mobile subscribers.

In the United States, cellular licenses are awarded by the Federal Communications Commission (FCC) pursuant to a licensing scheme which divides the country into geographic service markets defined according to the 1980 Census. Only two cellular licenses are awarded for each market. The two cellular systems in each market are commonly referred to as the "A" system and "B" system, respectively. Each of the two systems is allocated a different frequency block in the 800 MHz band (called the A-band and B-band, respectively). To date, the FCC has released a total of 50 Mhz for cellular services (25 MHz per system).

Mobile subscribers have the freedom to subscribe to service from either the A-system or the B-system operator (or both). The local system from which service is subscribed is called the "home" system. When travelling ("roaming") outside the home system, a mobile subscriber may be able to obtain service in a distant system if there is a roaming agreement between the operators of the home and "visited" systems.

The Cellular System

In a typical cellular radio system, a geographical area, e.g., a metropolitan area, is divided into several radio coverage areas (called cells). The cells are served by a series of fixed radio stations (called base stations). The base stations are connected to and controlled by a mobile services switching center (MSC). The MSC, in turn, is connected to the landline (wireline) public switched telephone network (PSTN). The telephone users (mobile subscribers) in the cellular radio system are provided with portable (hand-held), transportable (hand-carried) or mobile (car-mounted) telephone units (mobile stations) which communicate with the MSC through a nearby base station. The MSC switches calls between wireline and mobile subscribers, controls signalling to the mobile stations, compiles billing statistics, and provides for the operation, maintenance and testing of the system.

Each of the cells in a cellular radio system is allocated a subset of the radio frequency (RF) channels assigned to the entire cellular system (25 MHz). Each RF channel consists of a pair of separate frequencies, one for transmission by the base station (reception by the mobile station) and one for transmission by the mobile station (reception by the base station). One of the RF channels in each cell (called the control channel) is used to carry control data (supervisory data messages) between the base station and the mobile stations in the cell. The other RF channels are used to carry voice conversations. The RF (control and voice) channels used in any given cell may be reused in a distant cell in accordance with a predetermined frequency reuse pattern. The base station in each cell includes a number of transceivers, each of which operates on only one of the different RF channels used in the cell. The transceiver in each mobile station, on the other hand, may tune to any of the RF channels specified in the system.

During the idle state (turned on but not in use), a mobile station in a cell tunes to and monitors the control channel. When a wireline subscriber calls a mobile subscriber, the call is directed from the PSTN to the MSC which requests the base stations to "page" the mobile station over each of their control channels. If the MSC receives a response from the mobile station (which occurs automatically if the mobile station is turned on), the MSC assigns the mobile station an available voice channel at the closest base station, turns the selected voice channel transceiver on, and orders the mobile station to tune to the selected voice channel where a voice connection is then established. If the mobile station moves between cells while in the conversation state, the MSC will order a "handoff" of the call to an available voice channel at the new base station. A similar procedure is used for mobile originations.

A mobile station gains access to a cellular system by qualifying for service in the cellular system. For this purpose, each mobile station is identified by a mobile identification number (MIN) and an electronic serial number (ESN). The MIN is a 34-bit binary number which is derived from the directory telephone number of the mobile subscriber, and which is usually programmed into the mobile station at the time of service installation. The ESN is a 32-bit binary number which is unique to each mobile station, and which is set at the factory, not to be altered in the field. At every system access, e.g., call origination, the MIN/ESN pair is sent over the control channel from the mobile station (through a nearby base station) to the MSC (for incoming calls, the MIN is included in the page message sent over the control channel to the mobile station). The MSC will determine whether the received MIN/ESN pair belongs to a "home" subscriber or to an authorized "roamer" from another system (the MSC may also compare the received ESN to a "blacklist" of mobile stations which have been reported to be stolen). If the MIN/ESN pair is not recognized or if the ESN is blacklisted, the mobile station will be denied access.

The Migration from Analog to Digital

Until recently, the radio transmission format in cellular systems has been analog frequency modulation (FM). With FM, a sinusoidal carrier wave at the transmit or receive frequency of the RF channel is modulated (varied) in proportion to the instantaneous amplitude of the analog

voice signal. The modulated carrier occupies a region of the spectrum about the carrier frequency. This region is called the channel bandwidth and is usually 30 KHz wide. Each analog voice conversation, therefore, requires a full RF channel (60 KHz).

Recent developments, however, have ushered a new digital era for cellular communications. The main driving force behind the switch to digital has been the desire to increase spectrum efficiency to meet the ever-increasing demands on system capacity. As each cellular system is allocated a finite amount of radio spectrum, capacity may be increased by reducing the amount of bandwidth required for each voice channel or, conversely, by sharing each RF channel among several voice conversations. This is made possible with the use of digital technology. By encoding (digitizing and compressing) and multiplexing speech from several voice circuits prior to modulation and transmission, a single RF channel may be shared by several digital speech channels, instead of carrying only one analog speech channel (one voice conversation).

In the United States, the migration from analog to digital has been spearheaded by the Electronics Industries Association (EIA) and the Telecommunication Industry Association (TIA) which have adopted an interim standard for the air interface in the new digital cellular systems. This EIA/TIA interim standard is known as the "Cellular System Dual-Mode Mobile Station-Base Station Compatibility Standard," or simply the "IS-54" standard (Rev. B of IS-54 is currently in effect: copies of this and any other revisions of IS-54 may be obtained from the Electronics Industries Association; 2001 Pennsylvania Avenue, N.W.; Washington, D.C. 20006). The term "dual-mode" refers to the capability of the system to operate in either an analog or digital mode. The analog mode of operation uses conventional analog FM. The digital mode of operation uses time division multiple access (TDMA) in which the RF channel is divided into a series of repeating time slots each containing a burst of encoded speech from a different source (e.g., a different voice circuit).

According to IS-54, each digital TDM RF channel can carry from three to six digital speech channels (three to six telephone conversations) depending on the source rate of the speech coder used for each digital speech channel. At call set-up, the dual-mode mobile stations may be assigned either an analog voice channel (an entire carrier frequency) or a digital traffic channel (a repeating time slot on a carrier frequency). The analog-only mobile stations, however, can only be assigned an analog voice channel.

Cellular Fraud

In addition to providing for a new, digital radio transmission format, IS-54 specifies a procedure for confirming the identity of mobile stations demanding service in a cellular system. A serious problem which has plagued the cellular industry for some time has been the widespread, fraudulent use of MIN/ESN pairs to steal cellular service. Many of the mobile stations in use today can be programmed to transmit any MIN/ESN pair so as to "trick" the system into granting access. Further background on this MIN/ESN "tumbling" and the resultant revenue and service losses can be found in the article entitled "Cellular Fraud" by Henry M. Kowalczyk, in *Cellular Business*, dated March 1991, at pp. 32–35.

Fraud in the form of MIN/ESN tumbling arose primarily in a "manual roaming" environment where the cellular systems were not interconnected on a real-time basis. Each MSC usually contains a list only of valid MIN/ESN pairs belonging to the home subscribers, and does not have immediate access to counterpart lists in other systems. Hence, by using a roamer MIN (a 10-digit directory telephone number containing an area code other than the local area code), a fraudulent mobile station could receive service from the local cellular system until an indication of the invalidity of the MIN/ESN pair has been received (hours later) from the home system of the pretending roamer (or from a clearing house). In an "automatic roaming" environment, however, the cellular systems are networked together on a real-time basis in accordance with the provisions of EIA/TIA Interim Standard IS-41 (or through a proprietary signalling protocol). Consequently, the serving cellular system can obtain verification of a MIN/ESN pair from a home system virtually immediately and can, therefore, deny service to a MIN/ESN tumbler without significant delay.

The real threat to automatic roaming is a new and elusive type of fraud known as "cloning" in which a fraudulent user adopts the bona fide MIN/ESN pair of a valid (paying) subscriber. The fraudulent user may surreptitiously acquire a bona fide MIN/ESN pair, or even a list of valid MIN/ESN pairs, in several ways. For example, in some instances, bona fide MIN/ESN numbers are printed on, and may be read from, a label which is affixed to a mobile station belonging to a valid subscriber. In other instances, a list of bona fide MIN/ESN pairs may be purchased on the "black market" or directly from an employee of the cellular operator. In addition, since each mobile station transmits the MIN/ESN pair to the serving exchange at every system access, one or more bona fide MIN/ESN pairs may be intercepted by listening to radio transmissions on the control channel.

Authentication

The new IS-54 standard offers a long-term solution to the problem of cellular fraud, including cloning, through a process called "authentication." The purpose of authentication is to enable a base station to confirm the identity of a mobile station through an exchange of information between the base station and the mobile station. For authentication to succeed, the base station and the mobile station must have identical sets of shared secret data (SSD). The SSD is stored in the MSC of the home system, or in a separate subscriber database called a "home location register" (HLR) connected to this MSC, and made available to the base station. Each mobile station also stores the SSD in memory.

In the process of authentication, the base station generates and sends to the mobile station a random bit pattern, called RAND or RANDU, on the control channel, analog voice channel (AVC) or digital traffic channel (DTC). Each of the mobile station and the base station uses RAND, a portion of SSD called SSD-A (the remaining portion, SSD-B, is used for encryption, and not for authentication), along with other input parameters, e.g., the MIN and ESN of the mobile station, in a Cellular Authentication and Voice Encryption (CAVE) algorithm, which is defined in Appendix A to IS-54, to generate an authentication response called AUTHR or AUTHU (depending on whether RAND or RANDU is used, respectively). The authentication response computed in the mobile station is sent to the base station to be compared with the authentication response computed in the base station. If the authentication responses match, authentication is considered successful, i.e., the base station and the mobile station are considered to have identical sets of SSD. However, if the comparison at the base station fails, the base

station may deny service to the mobile station or commence the process of updating the SSD.

The procedure for updating SSD for any mobile station involves the application of CAVE initialized with mobile station-specific information (ESN), certain random data (RANDSSD), and a secret, permanent authentication key, called the "A-key," which is uniquely assigned to the mobile station. For security reasons, the A-key is never transmitted over the air interface between the base station and the mobile station, or over the network interface between different cellular systems. The A-key is stored in the MSC or the HLR and must be entered into the memory of the mobile station for use in updating the SSD. The default value of the A-key when the mobile station is shipped from the factory will be all binary zeros. The operational value of the A-key is assigned by the system operator when a mobile subscriber signs up for service. The assigned A-key value will be delivered to the subscriber in person, through the postal services (e.g., registered mail), or in some other convenient method determined by the operator.

At present, entry of the A-key into the mobile station is slated to be handled by authorized technicians at the time of mobile service activation. The A-key is to be programmed using a special facility provided in every mobile station sold, called the number administration module (NAM) programming mode, which allows the setup and configuration of the mobile station through the entry of system-specific parameters (e.g., control channel number and system identification number (SID)), and subscriber-specific parameters (e.g., the user MIN and lock code) at the time of installation or service. NAM programming requires a qualified technician with access to the installation and service directions specified by the mobile station manufacturer.

Relying only on NAM programming for A-key entry limits A-key programming access. By its very nature, NAM programming is far beyond the skills and capabilities of the average individual (or mobile subscriber) and is normally left to the professionals. Even where an individual has some knowledge of NAM programming, it is not desirable for the individual to invoke the NAM programming mode in the mobile station merely to enter the A-key value, because of the risk of inadvertent tampering with the values of all the other critical parameters which are stored in the mobile station and which are accessible during NAM programming.

It is, therefore, an object of the present invention to provide a means to enter the A-key which is separate from NAM programming, which is relatively easy to use (user-friendly), and which requires no special technical knowledge to use.

It is another object of the present invention to notify the user of whether the A-key entered is valid or invalid, and to allow the user to edit his entry.

It is yet another object of the present invention to allow the use of multiple A-keys for multiple MINs stored in the mobile station.

SUMMARY OF THE INVENTION

In one aspect, the present invention provides a mobile station which may be operated in both a set-up programming mode and in an authentication key programming mode. The authentication key programming mode may be invoked through a series of keystrokes on a keypad in the mobile station.

In another aspect, a mobile station constructed in accordance with the present invention includes means for entering secret data into the mobile station, means for validating the entered secret data, and means for generating an external indication of the validity of the entered secret data. The external indication may be a text string which is shown on a display in the mobile station.

In yet another aspect, the present invention provides a method for entering authentication information into a mobile station which is assigned at least one mobile identification number (MIN) stored in the mobile station. The method includes the steps of assigning a separate authentication key (A-key) for each MIN, displaying in the mobile station an indication of any stored MIN in response to a user-entered command, receiving in the mobile station a value of the A-key to be associated with the indicated MIN, validating the received value of the A-key through an authentication algorithm executed in the mobile station, and storing in the mobile station the received A-key value in association with the indicated MIN if the A-key value is determined to be valid.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be better understood and its numerous objects and advantages will become apparent to those skilled in the art by reference to the following drawings in which:

FIG. 1 is a pictorial representation of an exemplary handset for a mobile station constructed in accordance with the present invention;

FIG. 2 is a simplified flow chart diagram which illustrates the tasks performed by a mobile station constructed in accordance with the present invention;

FIG. 3 is a block diagram which illustrates the separate A-key entry process of the present invention; and

FIG. 4 is a flow chart diagram of the steps executed in a mobile station during A-key entry in accordance with the present invention.

DETAILED DESCRIPTION

Referring first to FIG. 1, a pictorial illustration of an exemplary mobile station handset may now be seen. The handset 10 includes a power (on/off) button 12, a speaker 14 (the microphone is on the other side of the handset 10 and is not shown), an alphanumeric keypad 16, a display (including a display window) 18, and a number of control or function keys: a "SEND" key 20, an "END" key 22, repeat dial buttons ("A" and "B") 24, a recall ("RCL") key 26, a store ("STO") key 28, a function ("FCN") key 30, a clear ("CLR") key 32, and "up" and "down" keys 34.

With continuing reference to FIG. 1, the SEND button 20 is pushed after all the dialed digits have been entered with the keypad 16 when making a call. The END key 22 is used to end a conversation ("hang-up" the phone), or to exit from any available programming mode. The repeat dial keys 24 are used for rapid, one-touch dialing of two frequently called phone numbers. The RCL key 26 is used to recall prior entries from memory. The STO key 28 is used to store a list of phone numbers in memory, and to store entries during the programming mode. The FCN key 30 is pressed to enter a given programming mode. The CLR key 32 clears (erases from the display) the last key entry. The up and down keys 34 are used for scrolling while in any programming mode, and for volume control at all other times. Many of these control or function keys, and the alphanumeric keypad 14, may be used in the present invention.

Referring next to FIG. 2, a simplified flow chart diagram of the tasks performed by a mobile station constructed in accordance with the present invention may now be seen. For the sake of convenience, the mobile station is first assumed to be turned off. At block 40, the user pushes the power button 12 and turns the mobile station on. At block 42, the mobile station executes the normal initialization or idle call processing procedures including the processing of messages received over the control channel, e.g., overhead and page messages. At block 44, the user enters a distinct series of keystrokes on the handset 10 to invoke any one of several processes available to the user. The user may choose to enter NAM programming mode at block 46, MENU mode at block 48, or A-key programming mode at block 50 Alternatively, the user may originate or answer a call, or invoke some other available process, at block 52.

As described heretofore, NAM programming is used to set certain basic parameters in the mobile station. NAM programming is usually completed by a skilled technician at the time of installation, and the average mobile subscriber is normally not even aware of the NAM programming capability, or the particular set of keystrokes required to enter NAM programming. Although the procedures for entering NAM programming vary among the different manufacturers (and models) of mobile stations, a typical procedure may involve the depression of a unique series of digits and then the function key. For example, to enter NAM programming with the handset 10 shown in FIG. 1, the user may press a series of digits on the keypad 16 and then push the function key 30 twice. Thereafter, the user is in NAM programming mode and he or she may scroll through a list of parameters using the up and down keys 34, and (at each stop) may enter a value for each parameter using the keypad 16. When finished, the user can push the end key 22 to exit NAM programming.

The MENU mode allows the user to select from a menu of user options and mobile phone features. For example, the user may choose to illuminate the keypad 16 from a background light, to "lock" the mobile station to prevent unauthorized use (the mobile station can then be "unlocked" by keying in a lock code), to activate a timer on the display 18 which measures the duration of each call, to switch from system A to system B (or vice versa), or to set the manner in which the user prefers to answer incoming calls (e.g., by pressing one of the digits on the keypad 16). To enter the MENU mode, the user may simply push the function key 30 twice (again, the exact procedure for entering MENU mode depends on the make and model of the mobile station; pushing the function key (once or twice), however, is a common way to enter MENU mode).

According to the present invention, the authentication key (A-key) may be entered into the mobile station not only through NAM programming (indicated at block 46 in FIG. 2), but also through a separate (and more user-friendly) A-key programming process (indicated at block 50 in FIG. 2). With the present invention, even a layman, who is not skilled in the detailed mobile phone programming methods (e.g., NAM programming), can easily program the A-key into the mobile station. The user need only know the special access code for entering A-key and the value of the A-key itself. This avoids the inconvenience of requiring mobile subscribers to have their A-keys programmed by qualified agents of the cellular system operator at perhaps remote centers. Instead, the operator, for example, may simply mail the A-key value to the mobile subscriber for convenient entry into the mobile station in the privacy of his or her home.

Referring next to FIG. 3, a block diagram which illustrates the separate A-key entry process of the present invention may now be seen. FIG. 3 shows, in block diagram form, a cellular system which includes a home location register (HLR) 60 of the local system operator (home carrier), and a mobile station 62 for a home subscriber. Each of the HLR 60 and the mobile station 62 includes a memory for storing the A-key assigned to the mobile subscriber by the home carrier, and other cryptovariables (authentication information) associated with the MIN assigned to this mobile subscriber, e.g., the shared secret data (SSD-A and SSD-B), and a call history parameter known as COUNT (according to IS-54, COUNT is a modulo-64 counter which is maintained in the mobile station and updated at the mobile station upon receipt of an update order from the base station on the AVC or DTC).

The mobile station 62 of FIG. 3 may actually store a plurality of sets of cryptovariables, one for each MIN assigned to the mobile subscriber. To avoid roamer charges when travelling away from the "home" system, a mobile subscriber may subscribe to service from several systems at once and, hence, have multiple MINs issued by different "home" carriers (multiple subscriptions). When entering the service area of any of these carriers, the mobile subscriber selects the MIN issued by the corresponding carrier to be active in the mobile station (the mobile subscriber can alternate between MINs using the function key, for example). The mobile subscriber thus becomes a home subscriber in the new system for billing and all other purposes. For these multiple MIN mobile stations, multiple A-keys (and multiple sets of the other cryptovariables) are required, one for each MIN. This is due to the restrictions imposed by IS-54 to enhance the security of the A-key, as explained below.

Each home carrier stores the A-key and other cryptovariables for each home subscriber (a given MIN/ESN combination) in its HLR for use in authenticating the mobile station (at system access, for example) and in updating the SSD. According to IS-54, the A-key is known only to the mobile station and the HLR of the home carrier, and is not passed from system to system as the mobile subscriber roams. Thus, SSD updates (in which the A-key is used to generate new SSD values) are carried out only in the mobile station and its associated HLR, and not in the serving system. As shown in FIG. 3, when the mobile station is roaming, the serving system obtains copies of cryptovariables like COUNT, SSD-A and SSD-B (but not the A-key) for the mobile station from its associated HLR via the IS-41 intersystem link.

When the user of a multiple MIN mobile station travels from an old "home" system to a new "home" system and activates the MIN for the new system, the computation of SSD updates will shift from the old home system to the new home system. However, because the new home system does not have access to the A-key used in the old home system, the new home system cannot complete an SSD update in the mobile station (the A-key is needed to generate new SSD values). To allow SSD updates in a multiple MIN mobile station, a separate A-key must be issued for each MIN/ESN combination and stored in the HLR of the corresponding home system (since other cryptovariables, e.g., SSD-A and SSD-B, are derived from the A-key, each home system must also store a separate set of cryptovariables for the corresponding MIN/ESN combination).

Returning to FIG. 3, each home carrier will issue an A-key to the mobile subscriber. The carrier may give the value of the A-key to the mobile subscriber in person, by telephone, or through the mail (according to Appendix A to IS-54, the

A-key is at least 6 but not more than 26 digits long). Once the mobile subscriber receives the A-key value from the carrier, the task of entering the A-key into the mobile station at block 64 is made relatively simple by the present invention, which provides a means (separate from NAM programming) to enter the A-key using the keypad 16 and the display 18 on the handset 10 of the mobile station (refer to the following discussion of FIG. 4 for a more detailed description of the A-key entry process). Once the A-key has been entered, a verification procedure (which is specified in Appendix A to IS-54) checks the accuracy of the manually-entered digits. As shown in FIG. 3, the entered A-key digits, along with an 8-bit constant called the Authentication Algorithm Version (AAV) stored in the mobile station and the ESN of the mobile station, are used as inputs to the CAVE algorithm 66 to validate the A-key. If the entered A-key is determined to be valid at decision block 68, the entered A-key digits are stored as the A-key for the currently-active MIN.

Referring next to FIG. 4, a flow chart diagram of the steps executed in a mobile station during A-key entry in accordance with the present invention may now be seen. At block 70, the user enters the separate A-key programming mode through a short series of keystrokes (a special A-key access code) different from the series of keystrokes used to access the NAM programming mode. The exact sequence of keystrokes used to reach the separate A-key programming mode is not material to the present invention but, for practical purposes, should be made easy for the user to remember. For example, the A-key access code could be selected to correspond to the letters "A"—"K"—"E"—"Y" on the keypad 16 (the digits 2—5—3—9). The user can then simply press the sequence 2539 followed by the function key 30 (twice) to enter the A-key programming mode.

Once the user reaches the A-key programming mode, the user can proceed to enter the digits of the A-key. For multiple MIN mobile stations, a separate A-key must be entered for each MIN and, further, the A-key issued by a home carrier must be entered for the MIN assigned by this home carrier and not for another MIN in the mobile station. To make the process of entering and associating the proper A-key with the corresponding MIN easier, the mobile station (MS) at block 72 displays an indication of the currently-active MIN (the MIN for the system in which the mobile station is currently operating), before the user begins to enter the digits of the first A-key. It is not necessary, however, for the MS to display the currently-active MIN instead of some other MIN in the MS since the user can scroll between the different MINs by pressing the up and down keys 34. The steps executed in the MS will be the same regardless of which A-key is being entered.

Assuming that the currently-active MIN is the first MIN to be displayed upon entering the A-key programming mode, the display 18 may show, for example, all 10 digits of the currently-active MIN, or some other alphanumeric designation for this MIN (e.g., "1" or "A" or "MIN1" or "A-key? 1" for the first MIN, "2" or "B" or "MIN2" or "A-key? 2" for the second MIN, etc.), or a combination of both. At decision block 74, the MS determines whether the user has pressed the end key 22 to exit from the A-key programming mode. If the end key 22 is pressed, the MS will return to processing other tasks. Otherwise, the MS remains in the A-key programming mode, ready to accept entry of the A-key digits (the MS, however, may exit from the A-key programming mode if a predetermined amount of time elapses without any user activity).

At block 76, the user enters on the keypad 16 the six to twenty six digits of the A-key for the MIN indicated on the display 18 (the currently-active MIN, or another MIN to which the user has scrolled). When the user starts to enter the A-key digits, a part or all of the MIN indication may disappear from the display 18 to make room for displaying the A-key digits, which are displayed as they are being entered. If the user makes a mistake, he or she may clear all or part of the entered number by using the clear button 32. After the entire digit sequence has been keyed in, the user will press the store button 28 (twice) to store the complete number. At this point, the MS will validate the entered A-key through the CAVE algorithm.

At block 78, the CAVE algorithm is initialized with the entered A-key digits, ESN, and AAV, and then executed in the manner specified by Appendix A to IS-54. At decision block 80, the MS determines whether the A-key entered by the user is valid. If the entered A-key number is valid, the display 18 at block 82 will provide an indication of validity to the user (e.g., the word "valid" or "OK" on the display 18, or an audible positive tone out of the speaker 14), and the MS will associate the number with the corresponding MIN in memory (if an old A-key exists in memory, the new A-key will overwrite the old A-key). Conversely, if the entered A-key number is invalid, the display 18 at block 84 will provide an indication of invalidity to the user (e.g., the word "invalid" or the words "try again," or an audible negative tone). In either case, the user can press the end key 22 to exit the A-key programming mode, attempt to reenter the A-key correctly, or scroll to another MIN for entry of the corresponding A-key.

The foregoing detailed description shows only certain particular embodiments of the present invention. However, those skilled in the art will recognize that many modifications and variations may be made without departing substantially from the spirit and scope of the present invention. Accordingly, it should be clearly understood that the form of the invention described herein is exemplary only and is not intended as a limitation on the scope of the invention as defined in the following claims.

What is claimed is:

1. A mobile station comprising:

a plurality of data entry keys;

means for operating said mobile station in a plurality of programming modes including an authentication key programming mode and a number administration module (NAM) programming mode;

means for enabling the selection of one of said programming modes through said data entry keys;

a memory containing at least one mobile identification number (MIN);

means for receiving an authentication key (A-key) entered by the user while said authentication key programming mode is selected; and

means for storing the entered A-key with said at least one MIN in said memory.

2. The mobile station of claim 1 wherein said authentication key programming mode is selected through a unique series of keystrokes.

3. The mobile station of claim 1 wherein said mobile station stores in said memory a plurality of mobile identification numbers (MINs), and wherein:

said receiving means comprises means for prompting the user to enter an authentication key (A-key) for each of said MINs; and

said storing means comprises means for storing the entered A-key with the corresponding MIN in said memory.

4. The mobile station of claim 3 further comprising means for validating the entered A-key prior to being stored with the corresponding MIN in said memory.

5. The mobile station of claim 4 further comprising means for generating an audible or visual indication of whether the entered A-key is valid.

6. A method for entering authentication information into a mobile station which is assigned at least one mobile identification number (MIN), said at least one MIN being stored in said mobile station, comprising the steps of:

assigning a separate authentication key (A-key) for each of said at least one MIN stored in said mobile station;

displaying in said mobile station an indication of any stored MIN in response to a user-entered command;

receiving in said mobile station a value of the A-key entered by the user for storing with the indicated MIN;

validating the received value of the A-key through an authentication algorithm executed in said mobile station;

storing in said mobile station the received A-key value with the indicated MIN if the received A-key value is determined to be valid; and

arranging said mobile station to receive new value of the A-key, to be entered by the user for storing with the indicated MIN or another MIN, if the received A-key value is determined to be invalid.

7. The method of claim 6 wherein said mobile station operates in at least two modes, including a set-up programming mode and an A-key programming mode, and wherein said user-entered command invokes said A-key programming mode.

8. The method of claim 6 further comprising the step of displaying an indication of the validity of the received A-key value as determined from the execution of said authentication algorithm.

9. The method of claim 6 wherein said mobile station stores the MIN corresponding to the system in which said mobile station is operating, and at least one other MIN corresponding to a different system, and wherein said displaying step comprises the steps of:

displaying an indication of the MIN corresponding to the system in which said mobile station is operating; and

displaying an indication of another MIN in response to a user-entered command, said indication of another MIN replacing said indication of the operating MIN.

10. The method of claim 6 wherein said MIN indication comprises the value of the MIN.

11. A system for entering authentication information into a mobile station which is assigned at least one mobile identification number (MIN), said at least one MIN being stored in said mobile station, comprising:

means for assigning a separate authentication key (A-key) for each of said at least one MIN;

means for displaying in said mobile station an indication of any one of said at least one MIN in response to a user-entered command;

means for receiving in said mobile station a value of the A-key entered by the user for storing with the indicated MIN;

means for validating the received value of the A-key through an authentication algorithm executed in said mobile station;

means for storing in said mobile station the received A-key value with the indicated MIN if the received A-key value is determined to be valid; and

means for receiving in said mobile station a new value of the A-key, entered by the user for storing with the indicated MIN or another MIN, if the received A-key value is determined to be invalid.

12. The system of claim 11 wherein said mobile station operates in at least two modes, including a set-up programming mode and an A-key programming mode, and wherein said user-entered command invokes said A-key programming mode.

13. The system of claim 11 further comprising means for displaying an indication of the validity of the received A-key value as determined from the execution of said authentication algorithm.

14. The system of claim 11 wherein said mobile station stores the MIN corresponding to the system in which said mobile station is operating, and at least one other MIN corresponding to a different system, and wherein said means for displaying comprises:

means for displaying an indication of the MIN corresponding to the system in which said mobile station is operating; and

means for displaying an indication of another MIN in response to a user-entered command, said indication of another MIN replacing said indication of the operating MIN.

15. The system of claim 11 wherein said MIN indication comprises the value of the MIN.

* * * * *

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United States Patent [19]

Minde

[11] Patent Number: 5,193,140

[45] Date of Patent: Mar. 9, 1993

[54] EXCITATION PULSE POSITIONING METHOD IN A LINEAR PREDICTIVE SPEECH CODER

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[22] Filed: Mar. 30, 1990

[30] Foreign Application Priority Data

May 11, 1989 [SE] Sweden 8901697

[51] Int. Cl.[5] G10L 9/14

[52] U.S. Cl. 395/2; 381/38

[58] Field of Search 381/29-41; 364/513.5

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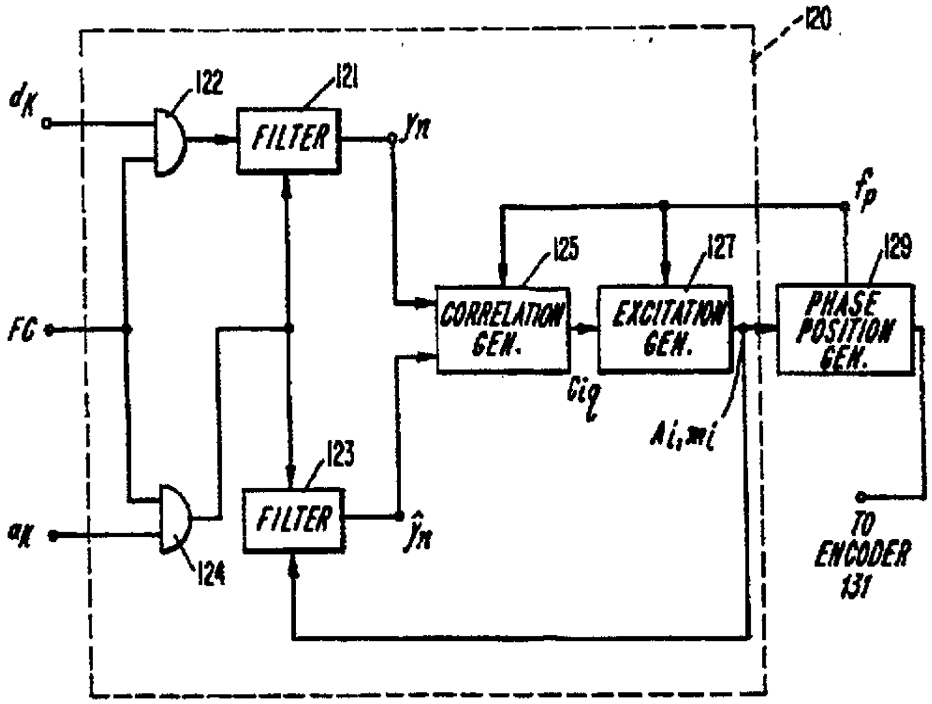
Primary Examiner—Michael R. Fleming
Assistant Examiner—Michelle Doerrler
Attorney, Agent, or Firm—Burns, Doane, Swecker & Mathis

[57] ABSTRACT

A method for positioning excitation pulses for a linear predictive coder (LPC) operating according to the multi-pulse principle, i.e. a number of such pulses are positioned at specific time points and with specific amplitudes. The time points and the amplitudes are determined from the predictive parameters (a_k) and the predictive residue signal (d_k), by correlation between a speech representative signal (y) and a composed synthesized signal ($\hat{y}$). All possible time positions for the excitation pulses within a given frame interval are provided. The possible time positions are divided into a number (n_f) of phase positions and each phase position is divided into a number of phases (f). All phases are vacant for the first excitation pulse. When this pulse has been positioned, the phase determined for this pulse is denied to the following excitation pulses until all pulses in a frame have been positioned.

4 Claims, 5 Drawing Sheets



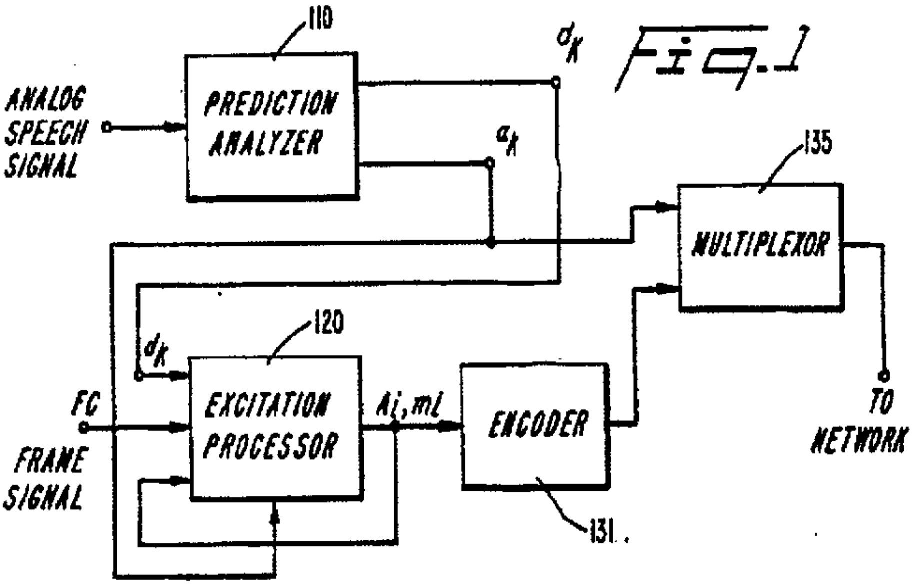


Fig. 1

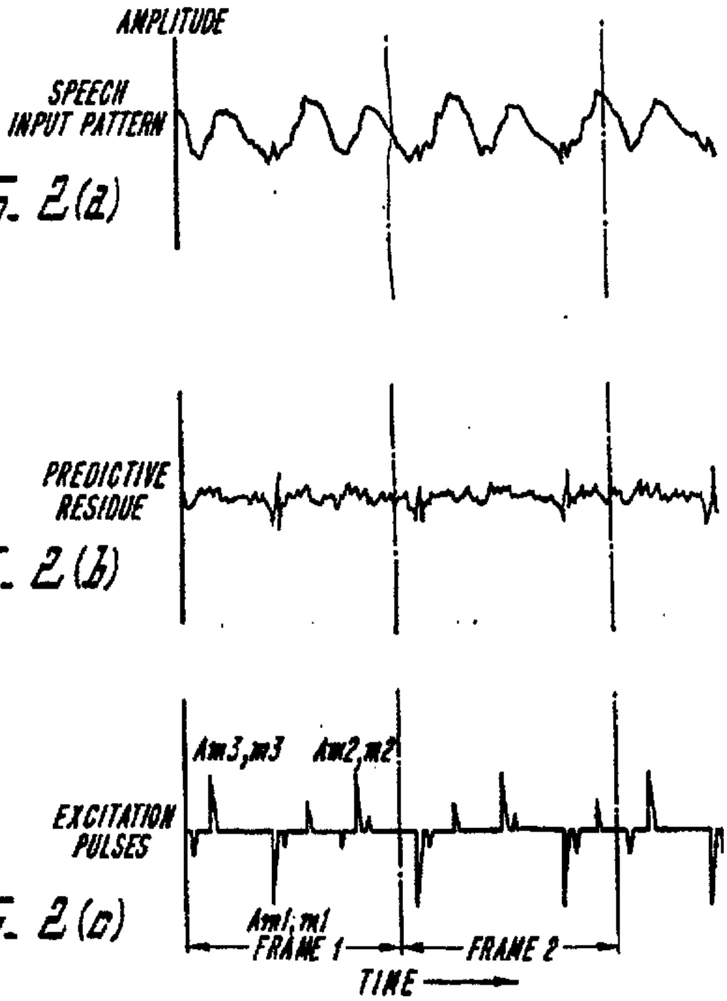


Fig. 2(a)

Fig. 2(b)

Fig. 2(c)

Fig. 3

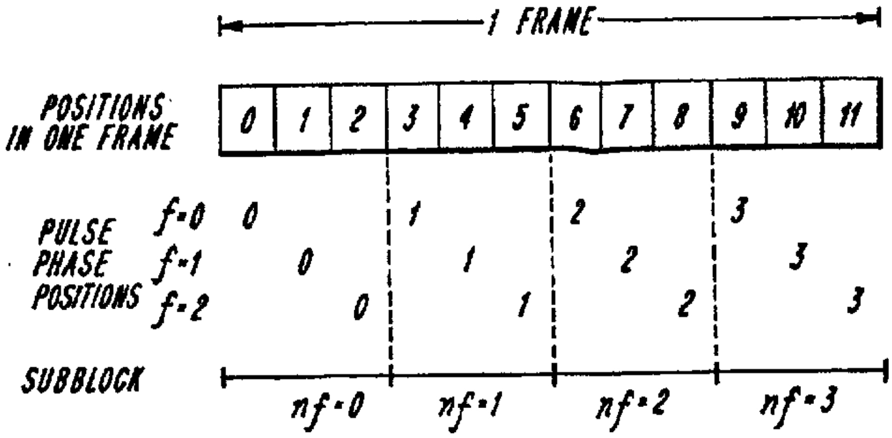
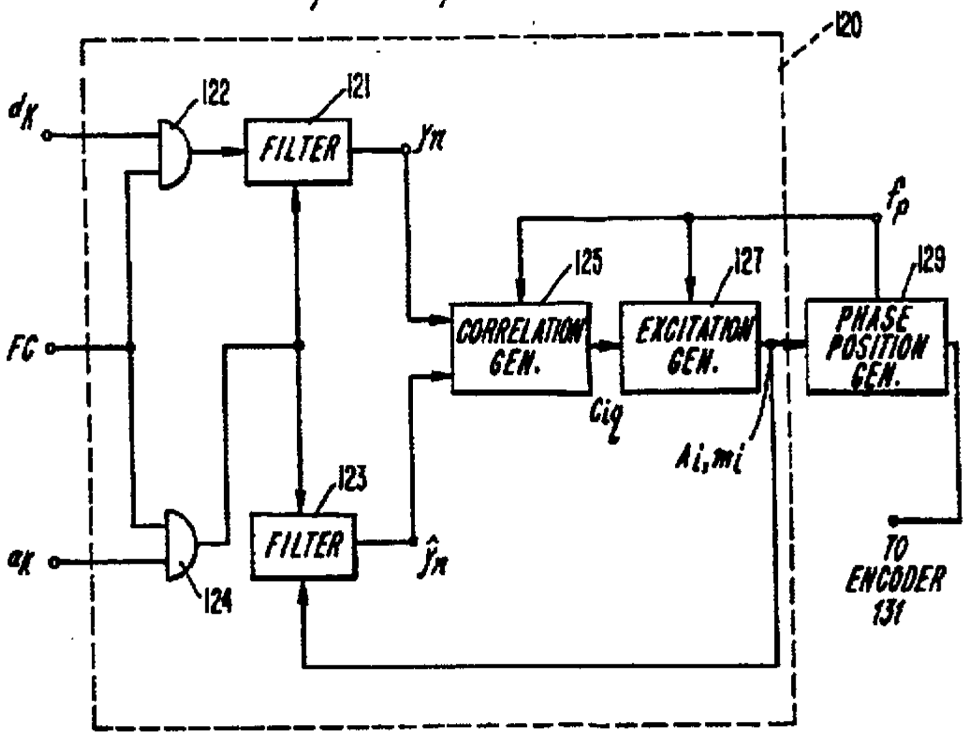

1 FRAME
POSITIONS IN ONE FRAME
0 1 2 3 4 5 6 7 8 9 10 11
PULSE PHASE POSITIONS
f=0
f=1
f=2
SUBBLOCK
nf=0
nf=1
nf=2
nf=3

Fig. 5


120
d_K
122
121
FILTER
y_n
f_p
125
127
129
CORRELATION GEN.
EXCITATION GEN.
PHASE POSITION GEN.
FC
C_{iq}
A_i, m_i
123
FILTER
a_K
124
$\hat{y}_n$
TO ENCODER 131

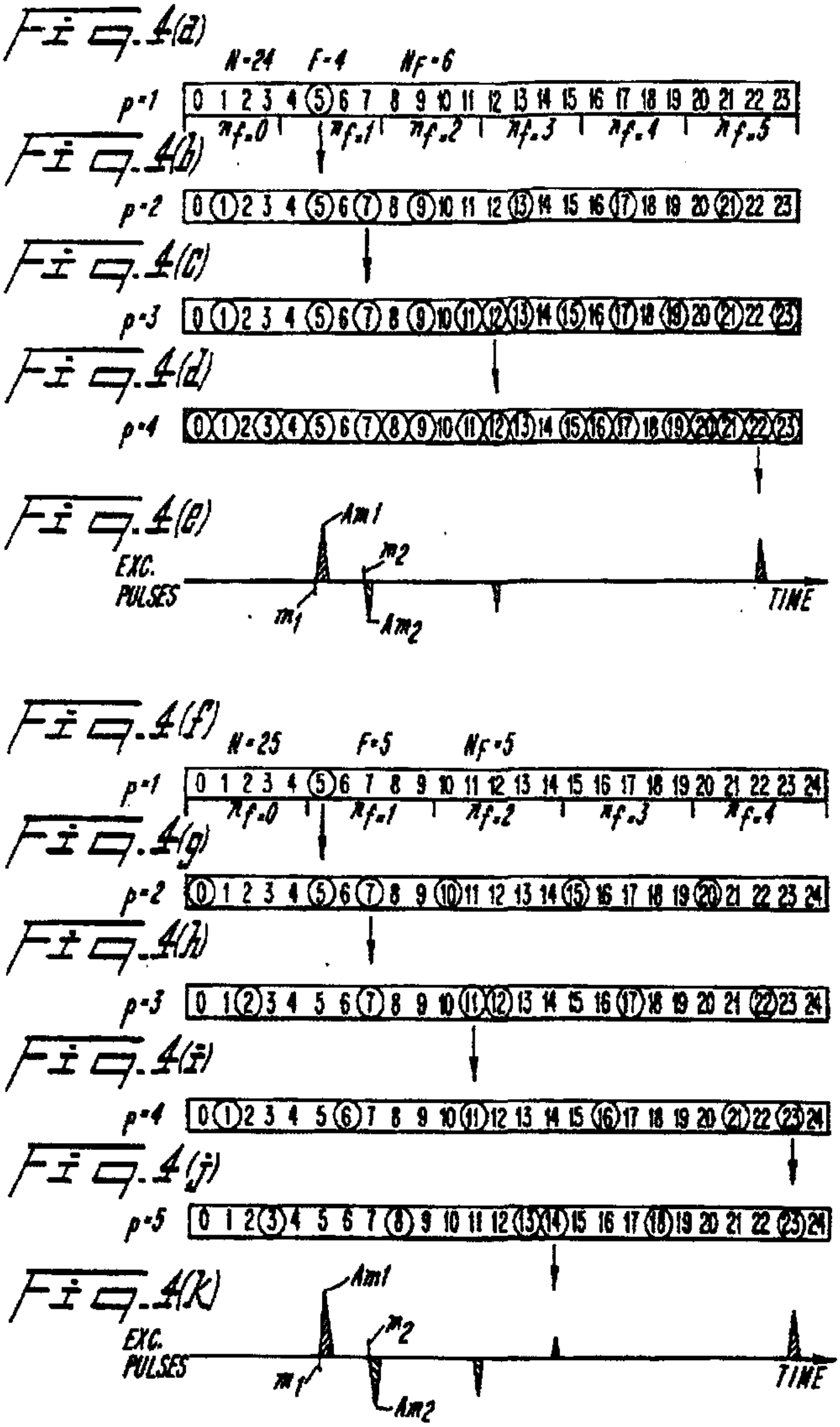
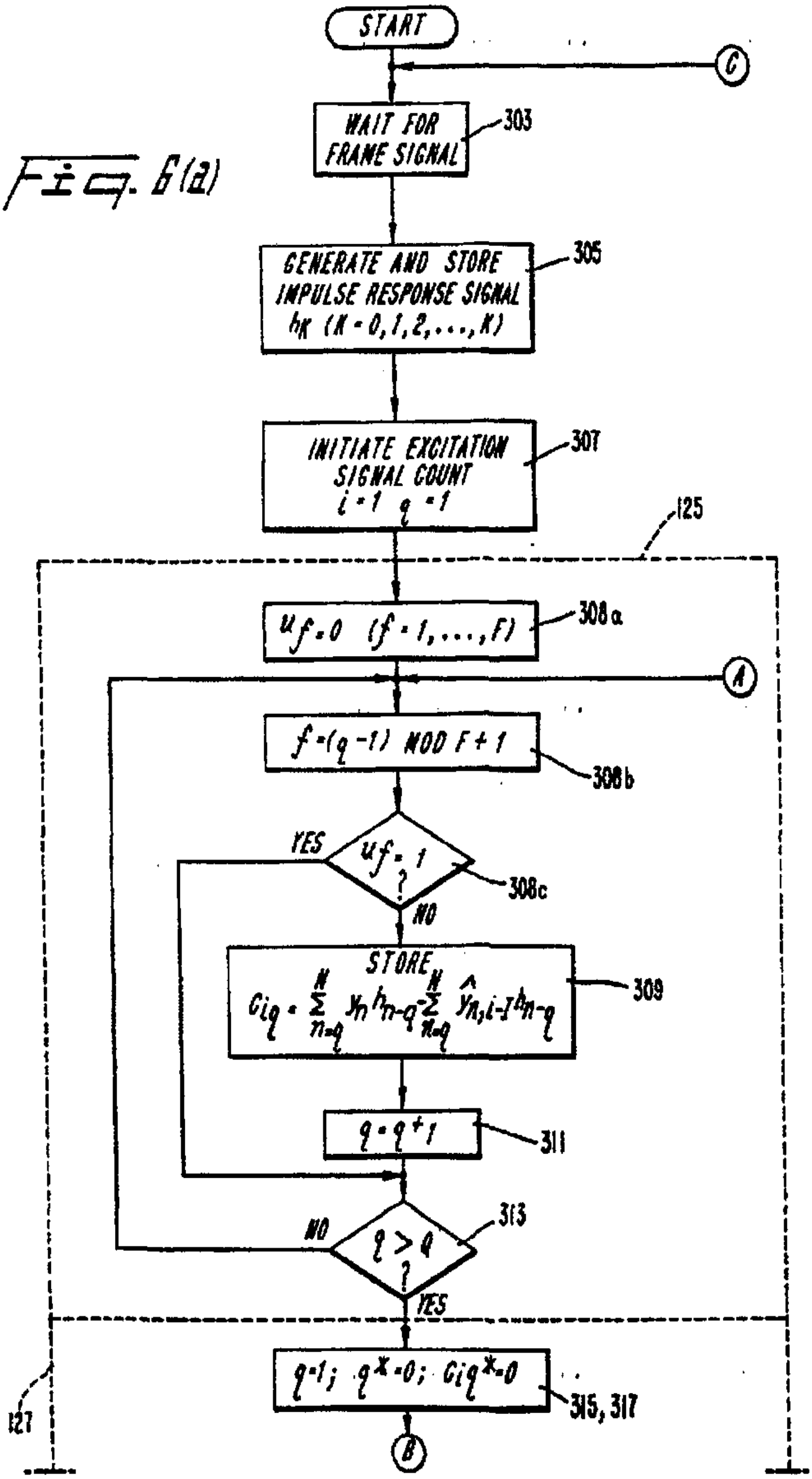


Fig. 4(a)
N=24 F=4 N_F=6
p=1
Fig. 4(b)
p=2
Fig. 4(c)
p=3
Fig. 4(d)
p=4
Fig. 4(e)
EXC. PULSES
Am1
m2
m1
Am2
TIME
Fig. 4(f)
N=25 F=5 N_F=5
p=1
Fig. 4(g)
p=2
Fig. 4(h)
p=3
Fig. 4(i)
p=4
Fig. 4(j)
p=5
Fig. 4(k)
EXC. PULSES
Am1
m2
m1
Am2
TIME

Fig. 6(a)


START
C
WAIT FOR FRAME SIGNAL
303
GENERATE AND STORE IMPULSE RESPONSE SIGNAL h_K (K = 0,1,2,...,K)
305
INITIATE EXCITATION SIGNAL COUNT i = 1 q = 1
307
125
$u_f = 0$ (f = 1,...,F)
308a
A
f = (q − 1) MOD F + 1
308b
YES
$u_f = 1$?
308c
NO
STORE $Ci_q = \sum_{n=q}^{N} y_n h_{n-q} - \sum_{n=q}^{N} \hat{y}_{n,i-1} h_{n-q}$
309
q = q + 1
311
313
NO
q > Q ?
YES
q = 1; $q^* = 0$; $Ci_q^* = 0$
315, 317
127
B

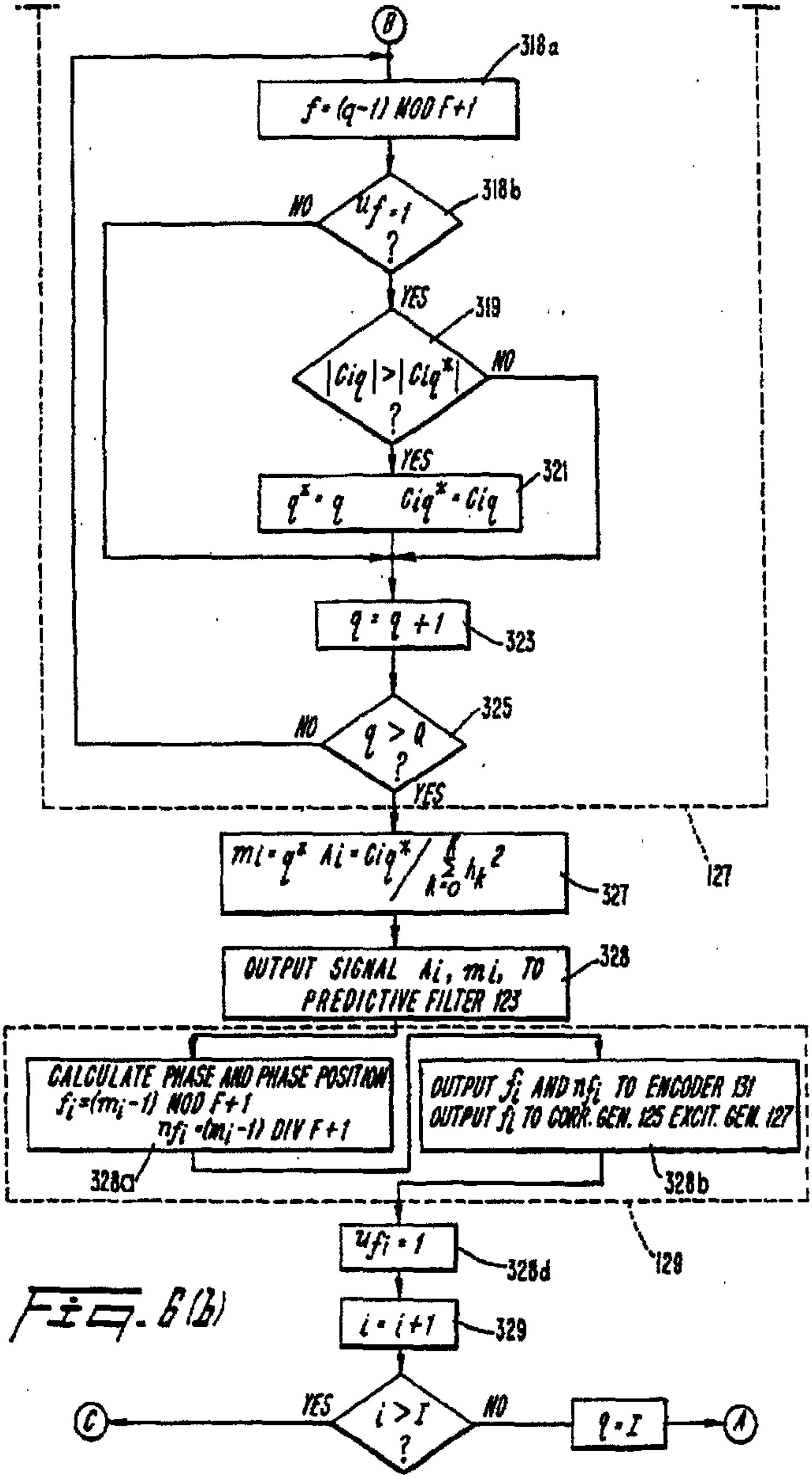

B
318a
f = (q-1) MOD F+1
NO
uf = 1 ?
318b
YES
319
|Ciq| > |Ciq*| ?
NO
YES
321
q* = q   Ciq* = Ciq
q = q + 1
323
325
NO
q > Q ?
YES
127
mi = q* Ai = Ciq* / Σ hk²
327
OUTPUT SIGNAL Ai, mi, TO PREDICTIVE FILTER 123
328
CALCULATE PHASE AND PHASE POSITION
fi = (mi-1) MOD F+1
nfi = (mi-1) DIV F+1
328a
OUTPUT fi AND nfi TO ENCODER 131
OUTPUT fi TO CORR. GEN. 125 EXCIT. GEN. 127
328b
129
ufi = 1
328d
i = i+1
329
C
YES
i > I ?
NO
q = I
A

FIG. 6(b)

EXCITATION PULSE POSITIONING METHOD IN A LINEAR PREDICTIVE SPEECH CODER

FIELD OF THE INVENTION

The present invention relates to a method of positioning excitation pulses in a linear predictive speech coder which operates according to the multi-pulse principle. Such a speech coder may be incorporated, for instance, in a mobile telephone system, for the purpose of compressing speech signals prior to transmission from a mobile.

BACKGROUND OF THE INVENTION

Linear predictive speech coders which operate according to the aforesaid multi-pulse principle are known to the art, from, for instance, U.S. Pat. No. 3,624,302, which describes linear predictive coding (LPC) of speech signals, and also from U.S. Pat. No. 3,740,476 which teaches how predictive parameters and predictive residue signals can be formed in such a speech coder.

When forming an artifical speech signal by means of linear predictive coding, there is generated from the original signal a number of predictive parameters (a_k) which characterize the synthesized speech signal. Thus, there can be formed with the aid of these parameters a speech signal which will not include the redundancy which is normally found in natural speech and the conversion of which is unnecessary when transmitting speech between, for instance, a mobile and a base station included in a mobile radio system. From the standpoint of conserving bandwidth, it is more appropriate to transfer solely predictive parameters instead of the original speech signal, which requires a much wider bandwidth. The speech signal regenerated in a receiver and constituting a synthetic speech signal can, however, be difficult to comprehend, due to a lack of agreement between the speech pattern of the original signal and the synthetic signal recreated with the aid of the prediction parameters. These deficiencies have been described in detail in U.S. Pat. No. 4,472,832 (SE-A-456618) and can be alleviated to some extent by the introduction of so-called excitation pulses (multi-pulses) when forming the synthetic speech copy. In this case, the original speech input pattern is divided into frame intervals. Within each such interval there is formed a given number of pulses of varying amplitude and phase position (time position), on the one hand in dependence on the prediction parameters a_k, and on the other hand in dependence on the predictive residue d_k between the speech input pattern and the speech copy. Each of the pulses is permitted to influence the speech pattern copy, so that the predictive residue will be as small as possible. The excitation pulses generated have a relatively low bit-rate and can therefore be coded and transmitted in a narrow band, as can also the prediction parameters. This results in an improvement in the quality of the regenerated speech signal.

In the case of the aforesaid known methods, the excitation pulses are generated within each frame interval of the speech input pattern, by weighting the residue signal d_k and by feeding-back and weighting the generated values of the excitation pulses, each in a separate predictive filter. The output signals from the two filters are then correlated. This is followed by maximization of the correlation of a number of signal elements from the correlated signal, therewith forming the parameters

(amplitude and phase position) of the excitation pulses. The advantage of this multi-pulse algorithm for generating excitation pulses is that various types of sound can be generated with a small number of pulses (e.g. 8 pulses per frame interval). The pulse searching algorithm is general with respect to the positioning of pulses in the frame. It is possible to recreate non-accentuated sounds (consonants), which normally require randomly positioned pulses, and accentuated sounds (vowels), which require more collected positioning of the pulses.

One drawback with the known pulse positioning method is that the coding effected subsequent to defining the pulse positions is complex with respect to both calculation and storage. Furthermore, the method requires a large number of bits for each pulse position in the frame interval. The bits in the code words obtained from the optimal combinatory pulse-coding algorithms are also prone to bit-error. A bit-error in the code word being transmitted from transmitter to receiver can have a disastrous consequence with regard to pulse positioning when decoding the code word in the receiver.

SUMMARY OF THE INVENTION

The present invention is based on the fact that the number of pulse positions for the excitation pulses within a frame interval is so large as to make it possible to forego exact positioning of one or more excitation pulses within the frame and still obtain a regenerated speech signal of acceptable quality subsequent to coding and transmission.

According to the known methods, the correct phase positions are calculated for the excitation pulses within one frame and following frames of the speech signal and positioning of the pulses is effected solely in dependence on complex processing of speech signal parameters (predictive residue, residue signal and the parameters of the excitation pulses in preceding frames).

According to the present inventive method, certain phase position limitations are introduced when positioning the pulses, by denying a given number of previously determined phase positions to those pulses which follow the phase position of an excitation pulse that has already been calculated. Subsequent to calculating the phase position of a first pulse within the frame and subsequent to placing this pulse in the calculated phase position, that phase position is denied to following pulses within the frame. This rule preferably applies to all pulse positions in the frame.

Accordingly, the object of the present invention is to provide a method for determining the positions of the excitation pulses within a frame interval and following frame intervals of a speech-input pattern to a linear predictive coder which requires a less complex coder and a smaller bandwidth and which will reduce the risk of bit-error in the subsequent recoding prior to transmission.

The proposed method may be applied with a speech coder which operates according to the multi-pulse principle with correlation of an original speech signal and the impulse response of an LPC-synthesized signal. The method can also be applied, however, with a so-called RPE-speech coder in which several excitation pulses are positioned in the frame interval simultaneously.

BRIEF DESCRIPTION OF DRAWINGS

The proposed method will now be described in more detail with reference to the accompanying drawings, in which

FIG. 1 is a simplified block schematic of a known LPC-speech-coder;

FIGS. 2(a)–2(c) are time diagrams which cover certain signals occurring in the speech coder according to FIG. 1;

FIG. 3 is a diagram explaining the principle of the invention;

FIGS. 4(a)–4(k) are more detailed diagrams illustrating the principle of the invention;

FIG. 5 is a block schematic illustrating a part of a speech coder which operates in accordance with the inventive principle; and

FIGS. 6(a)–6(b) are flow charts for the speech coder shown in FIG. 5.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

FIG. 1 is a simplified block schematic of a known LPC-speech-coder which operates according to the multi-pulse principle. One such coder is described in detail in U.S. Pat. No. 4,472,832 (SE-A-456618). An analogue speech signal from, for instance, a microphone occurs on the input of a prediction analyzer 110. In addition to an analogue-digital converter, the prediction analyzer 110 also includes an LPC-computer and a residue-signal generator, which form prediction parameters a_k and a residue-signal d_k respectively. The prediction parameters characterize the synthesized signal, whereas the residue signal shows the error between the synthesized signal and the original speech signal across the input of the analyzer.

An excitation processor 120 receives the two signals a_k and d_k and operates under one of a number of mutually sequential frame intervals determined by the frame signal FC, such as to emit a given number of excitation pulses during each of said intervals. Each of said pulses is determined by its amplitude A_{mp} and its time position, m_p within the frame. The excitation-pulse parameters A_{mp}, m_p are led to an encoder 131 and are thereafter multiplexed in a multiplexer 135 with the prediction parameters a_k, prior to transmission from a radio transmitter for instance.

The excitation processor 120 includes two predictive filters having the same impulse response for weighting the signals d_k and A_i, m_i in dependence on the prediction parameters a_k during a given computing or calculating stage p. Also included is a correlation signal generator which operates in each modification stage to effect correlation between the weighted original signal (y) and the weighted synthesized signal ($\hat{Y}$) each time an excitation pulse is to be generated. For each correlation there is obtained a number q of "candidates" of pulse elements A_i, m_i ($0 \leq i < I$), of which one candidate gives the smallest quadratic error or smallest absolute value. The amplitude A_{mp} and time position m_p for the selected "candidate" are calculated in the excitation signal generator. The contribution from the selected pulse A_{mp}, m_p is then subtracted from the desired signal in the correlation signal generator, so as to obtain a new sequence of "candidates", and the method is repeated for a number of times which equals the desired number of excitation pulses within a frame. This is described in detail in the aforesaid US-patent specification.

FIGS. 2(a)–2(c) are time diagrams over speech input signals, predictive residues d_k and excitation pulses, respectively. The number of excitation pulses in this example is eight (8), of which the pulse A_{ml}, m_l was selected first (gave the smallest error), and thereafter pulse A_{m2}, m_2, etc. within the frame.

In the earlier known method for calculating amplitude A_i and phase position m_i for each excitation pulse, $m_i = m_p$ is calculated for that pulse which gave maximum value of $\alpha i/\phi ij$, and associated amplitude A_{mp} was calculated, where αm is the cross-correlation vector between the signals y_n and $\hat{y}_n$ according to the above, and ϕmm is the auto-correlation matrix for the impulse response of the prediction filters. Any position m_p whatsoever is accepted when solely the above conditions are fulfilled. The index p signifies the stage under which calculation of an excitation pulse according to the above takes place.

In accordance with the invention, a frame according to FIG. 2 is divided in the manner illustrated in FIG. 3. It is assumed, by way of example, that the frame contains N=12 positions. In this case, the N-positions form a search vector (n). The whole of the frame is divided into so-called sub-blocks. Each sub-block will then contain a given number of phases. For instance, if the whole frame contains N=12 positions, in accordance with FIG. 3, four sub-blocks are obtained and each sub-block will contain three different phases. Each sub-block has a given position within the full frame, this position being referred to as the phase position. Each position n($0 \leq n < N$) will then belong to a given sub-block n_f ($0 \leq n_f < N_f$) and a given phase f ($0 \leq f < F$) in said sub-block.

In general the positions n ($0 \leq n < N$) in the total search vector, which contains N positions, will be

$$n = n_f F + f$$

$n_f = 0, \ldots,$
$(N_f - 1)$,
$f = 0, \ldots (F-1)$ and
$n = 0, \ldots, (N-1)$.

Furthermore, the following relationship will also apply

$$f = n \text{ MOD } F \text{ and } n_f = n \text{ DIV } F \quad (1)$$

The diagram of FIG. 3 illustrates the distribution of the phases f and sub-blocks n_f for a given search vector containing N positions. In this case, N=12, F=3 and N_F=4.

The inventive method implies limiting the pulse search to positions which do not belong to an occupied phase f_p for those excitation pulses whose positions n have been calculated in preceding stages.

In the following, the order or sequence number of a given calculating cycle of an excitation pulse is designated p, in accordance with the aforegoing. The proposed method will then result in the following calculation stages for a frame interval:

1. Calculate the desired signal Y_n
2. Calculate the cross-correlation vector α_i
3. Calculate the auto-correlation matrix ϕ_{ij}
4. When p=1. Search for m_p, i.e. the pulse position which gives maximum $\alpha_i/\phi_{ij} = \alpha_m/\phi mm$ in the unoccupied phases f.
5. Calculate the amplitude A_{mp} for the discovered pulse position m_p.
6. Update the cross-correlation vector α_i.

7. Calculate f_p and n_{fp} in accordance with the relationship (1) above, and

8. Carry out steps 4–7 above when p=p+1.

FIGS. 4(a)–4(k) are diagrams which illustrate a method for implementing the present invention.

FIG. 4(a)–4(e) illustrate an example in which the number of positions in a frame are N=24, the number of phases are F=4 and the number of phase positions are $N_F=6$.

It is assumed that no phases are occupied at the start p=1, and it is also assumed that the above calculating stages 1–4 gave the position $m_1=5$. This pulse position is marked with a circle in FIG. 4(a). This gives the phase 1 in respective phase positions $n_f=0,1,2,3,4$ and 5, and corresponding pulse positions are n=1, 5, 9, 13, 17 and 21 in accordance with the relationship (1) above. The phase 1 and corresponding pulse positions are thus occupied when calculating the position of the next excitation pulse (p=2). It is assumed that the calculating stage 4 for p=2 results in $m_2=7$. Possibly $m_2=9$ can have the maximum value of α_i/ϕ_{ij}, but this selection results in an occupied phase. The pulse position $m_2=7$ gives phase 3 in each of the phase positions $n_f=0, \ldots 5$, and means that the pulse positions n=3,7,11,15 and 22 will be occupied. The positions 1,3,5,7,9,11,13,15,17,19,21 and 23 are thus occupied before commencement of the next calculating stage (p=3).

It is assumed that the calculating stages 1–4 above for p=3 will give $m_3=12$, and that for p=4 the calculating stages result in the last position $m_4=22$. All positions in the frame are herewith occupied. FIG. 4(e) illustrates the excitation pulses (A_{m1}, m_1), (A_{m2}, m_2) etc., obtained.

FIGS. 4(f)–4(k) illustrates a further example, in which N=25, F=5 and $N_F=5$, i.e. the number of phases within each phase position has been increased by one. Pulse positioning is effected in the same manner as that according to FIGS. 4(a)–4(e) and finally five excitation pulses are obtained. The maximum number of excitation pulses obtained is thus equal to the number of phases within one phase position.

The obtained phases $f_1, \ldots, f_p$ (p=4 in FIGS. 4(a)–4(e) and p=5 in FIGS. 4(f)–4(k) are coded together and the resultant phase positions $n_{f1}, \ldots, n_{fp}$ are each coded per se prior to transmission. Combinatory coding can be employed for coding the phases. Each of the phase positions is coded with a code word per se.

In accordance with one embodiment, the known speech-processor circuit can be modified in the manner illustrated in FIG. 5, which illustrates that part of the speech processor which includes the excitation-signal generating circuits 120.

Each of the predictive residue-signals d_k and the excitation generator 127 are applied to a respective filter 121 and 123 in time with a frame signal FC, via the gates 122, 124. The filters 121, 123 produce the signals y_n and $\hat{y}_n$ which are correlated in the correlation generator 125. The signal y_n represents the true speech signal, whereas $\hat{y}_n$ represents the synthesized speech signal. There is obtained from the correlation generator 125 a signal C_{iq} which includes the components α_i and ϕ_{ij} in accordance with the aforegoing. A calculation is made in the excitation generator 127 of the pulse position m_p which gives maximum α_i/ϕ_{ij}, wherein the amplitude A_{mp} according to the aforegoing is obtained in addition to the pulse position m_p.

The excitation pulse parameters m_p, A_{mp} produced by the excitation generator 127 are sent to a phase generator 129. This generator calculates the current phases f_p and the phase positions n_{fp} from the values m_p, A_{mp} arriving from the excitation generator 127, in accordance with the relationship

$$f=(m-1)\text{ MOD } F+1$$

$$n_f=(m-1)\text{ DIV } F+1$$

where F=the number of possible phases.

The phase generator 129 may consist of a processor which includes a read memory operative to store instructions for calculating the phases and the phase positions in accordance with the above relationship.

Phase and phase position are then supplied to the encoder 131. This coder is of the same principle construction as the known coder, but is operative to code phase and phase position instead of the pulse positions m_p. On the receiver side, the phases and phase positions are decoded and the decoder thereafter calculates the pulse position m_p in accordance with the relationship

$$m_p=(n_{fp}-1)\cdot F+f_p$$

which gives a clear determination of the excitation-pulse position.

The phase f_p is also supplied to the correlation generator 125 and to the excitation generator 127. The correlation generator stores this phase and takes into account that this phase f_p is occupied. No values of the signal C_{iq} are calculated where q is included in those positions which belong to all preceding f_p calculated for an analyzed sequence. The occupied positions are

$$q=n\cdot F+f_p$$

where $n=0, \ldots, (N_f-1)$ and f_p signifies all preceding phases occupied within a frame. Similarly, the excitation generator 127 takes into account the occupied phases when making a comparison between the signals C_{iq} and C_{iq}^*.

When all pulse positions in respect of one frame have been calculated and processed and when the next frame is to be commenced, all phases will, of course, again be vacant for the first pulse in the new frame.

FIGS. 6(a) and 6(b) illustrate a flow chart which constitutes the flow chart illustrated in FIG. 3 of U.S. Pat. No. 4,472,832 which has been modified to include the phase limitation. Introduced between the blocks 327 and 329 (in place of block 328), which concern the calculation of the output signal m_p, A_{mp} of the phase generator 129 and recitation of position index p, is a block 328a which concerns the calculations to be carried out in the phase generator, and thereafter a block 328b which concerns the application of an output signal on the coder 131 and the generators 125 and 127. f_p and n_{fp} are calculated in accordance with the above relationship (1). There is then carried out in the generators 125 and 127 a vector allocation

$$n_{fi}=1$$

which is used when testing the obtained q-value=q* which gave the maximum value α_m/ϕ_{mm} with the intention of ascertaining whether a corresponding pulse position gives a phase which is occupied or vacant. This test is carried in blocks 308a, 308b, 308c (between the blocks 307 and 309) and in the blocks 318a, 318b (between the blocks 317, 319). The instructions given by the blocks

308a, b and c are carried out in the correlation generator 125, whereas the instructions given by the blocks 318a, b are carried out in the excitation generator 127.

Firstly the signal f, i.e. the phase, is calculated from the index q in accordance with the aforegoing, whereafter a test is carried out to ascertain whether the vector position for the phase f in the vector u_f is equal to 1. If $u_f=1$, which implies that the phase is occupied for precisely this index q*, no correlation-calculations are carried out in accordance with the instruction from block 309 and similarly the comparisons in block 319. On the other hand, when $u_f=0$ this indicates a vacant phase and the subsequent calculations are carried out as earlier.

The occupied phases shall remain during all calculated sequencies relating to a full frame interval, but shall be vacant at the beginning of a new frame interval. Consequently, subsequent to block 307 the vector u_f is set to zero prior to each new frame analysis.

When coding the positions m_p for the various excitation pulses within a frame, both the phase position n_{fp} and the phase f_p shall be coded. Coding of the positions is thus divided up into two separate code words having mutually different significance. In this case, the bits in the code words obtain mutually different significance, and consequently the sensitivity to bit-error will also be different. This dissimilarity is advantageous with regard to error correction or error detection channel-coding.

The aforedescribed limitation in the positioning of the excitation pulses means that coding of the pulse positions takes place at a lower bit-rate than when coding the positions in multi-pulse without said limitation. This also means that the search algorithm will be less complex than without this limitation. Admittedly, the inventive method involves certain limitations when positioning the pulses. A precise pulse position is not always possible, however, this limitation shall be weighed against the aforesaid advantages.

The inventive method has been described in the aforegoing with reference to a speech coder in which positioning of the excitation pulses is carried out one pulse at a time until a frame interval has been filled. Another type of speech coder described in EP-A-195 487 operates with positioning of a pulse pattern in which the time distance t_a between the pulses is constant instead of variable. The inventive method can also be applied with a speech coder of this kind. The forbidden positions in a frame therewith coincide with the positions of the pulses in a pulse pattern.

While a particular embodiment of the present invention has been described and illustrated, it should be understood that the invention is not limited thereto since modifications may be made by persons skilled in the art.

The present application contemplates any and all modifications that fall within the spirit and scope of the underlying invention disclosed and claimed herein.

I claim:

1. A method for positioning excitation pulses for a linear predictive coder and for coding positioning information wherein a synthesized speech signal is formed from an original speech signal, comprising:

(a) determining a number of predictive parameters which characterize said original speech signal within a time frame interval;

(b) calculating a residual signal representing an error between said original speech signal and said synthesized speech signal within said frame interval and generating an array of excitation pulses within said frame interval based on said residual signal and said predictive parameters;

(c) generating a weighted, speech-representative signal Y_n by weighting said residual signal with said predictive parameters;

(d) generating a weighted, synthesized speech signal $\hat{Y}_n$ by weighting a representative signal which represents an amplitude and a time position of one of said excitation pulses with said predictive parameters;

(e) correlating for each of a number of modification stages i said weighted speech-representative signal Y_n with said weighted synthesized speech signal $\hat{Y}_n$ to determine a difference signal for each of said stages;

(f) determining for each of said stages a candidate for an excitation pulse representing an amplitude A_i and a time position m_i from said correlation of that stage, determining the minimum value of said difference signal among the difference signals for all candidates and selecting the candidate which corresponds to said minimum value to obtain the amplitude A_{mp} and the time position m_p for one of said excitation pulses, and repeating the pulse candidate determination procedure for a desired number of excitation pulses in a frame disregarding excitation pulses determined in previous modification stages;

(g) dividing a total number of possible time positions n for excitation pulses within said time frame into a number of phase positions n_f, each phase position including a number of phases f such that $n=n_fF+f$, where F is a total number of phases f in a particular phase position n_f;

(h) determining according to steps (d) through (f) an amplitude and a time position of a first and subsequent excitation pulses among time positions n having corresponding phases in each phase position but not occupied by time positions of preceding excitation pulses until a preset number of excitation pulses determined within said time frame interval have been positioned;

(i) coding each determined phase position n_f separately to form separate code words; and

(j) coding said determined phases together to form a single code word.

2. A method according to claim 1, wherein a phase f_p and phase position n_{fp} corresponding to an amplitude and time position m_p determined for a particular excitation pulse p are calculated in accordance with the relationship

$$n_{fp}=(m_p-1) \text{ Mod } F+1$$

$$f_p=(m_p-1) \text{ Div } F+1$$

wherein only a value of said phase f_p in all phase positions n_f within said time frame interval determines which time position of an excitation pulse following said particular excitation pulse p shall be forbidden and wherein this procedure is repeated for each excitation pulse until a desired number of excitation pulses has been obtained within the frame.

3. A method according to claim 2, further comprising:

generating a test vector from the number f of pulse phases within one phase position n_f among a plurality of phase positions of a frame representing the

state of availability of each phase within said time frame;

determining a phase in said test vector corresponding to the determined time position according to step (h);

determining whether said determined phase is available for a particular phase position based on said test vector;

if said determined phase is not available, determining if a phase of another phase position is available;

if said particular phase is available, successively executing steps (e) and (f) for a next, pulse position; and

updating said test vector.

4. A method according to claim 1, further comprising:

generating a test vector from the number f of pulse phases within one phase position n_f among a plurality of phase positions of a frame representing the state of availability of each phase within each phase position in said time frame;

determining a phase in said test vector corresponding to the determined time position according to step (h);

determining whether said determined phase is available for a particular phase position based on said test vector;

if said determined phase is not available, determining if a phase of another phase position is available;

if said particular phase is available, successively executing steps (e) and (f) for a next, pulse position; and

updating said test vector.

* * * * *

#1036

MUTUAL NONDISCLOSURE AGREEMENT

THIS AGREEMENT is made and entered into as of this 4th day of December, 1989, by and between QUALCOMM, Inc. (hereinafter referred to as "QUALCOMM"), a California corporation with its principal place of business located at 10555 Sorrento Valley Road, San Diego, California 92121 and ERICSSON RADIO SYSTEMS, INC. (hereinafter referred to as "ERICSSON RADIO SYSTEMS"), with a principal place of business located at 709 North Glenville Drive, Richardson, TX 75081 (QUALCOMM and ERICSSON RADIO SYSTEMS hereinafter individually referred to as the "Party" or collectively the "Parties").

WHEREAS the Parties are in possession of certain Confidential and Proprietary Information (defined below) relating to cellular transmission systems and technologies (the "Technology").

WHEREAS the Parties agree it would be mutually advantageous to disclose to the other party their respective Confidential and Proprietary Information relating to the Technology for the sole purpose of evaluating the possibility of business transaction or other commercial arrangement between the Parties concerning the Technology (herein the "Program").

WHEREAS, the Party receiving and Confidential and Proprietary Information may use such information solely for the purpose of evaluating the feasibility of entering into a business transaction or other commercial arrangement with the disclosing Party on such terms and conditions to be mutually agreed upon between the Parties.

NOW, THEREFORE, FOR GOOD AND VALUABLE CONSIDERATION, the receipt and sufficiency of which is hereby acknowledged, it is hereby agreed as follows:

1. As used herein, "Confidential and Proprietary Information" shall mean all information relating to the evaluation and/or development of the Technology including but not limited to any invention, all information contained in any patent application, discovery, know-how, idea, trade secret, concept, work in progress, technique, formula, machine, method, process, use, apparatus, product, device, design specification, code, program, drawing, blueprint, diagram, formula, machine, use, marketing plans, customer names and other technical, confidential, financial, business or proprietary information which is disclosed in oral, written or sample form, by one Party to the other which, if written, is designated, labeled or marked with a confidential and/or proprietary legend on the document where such information appears.

2. Each Party (as the "Receiving Party") agrees to safeguard and protect all Confidential and Proprietary Information disclosed hereunder by the other (the "Disclosing Party"), to handle such information with the same degree of care and confidentiality as it efforts its own confidential and proprietary information of a similar nature and/or like significance, and not to "use" or allow other persons to use, said information at any time and in any manner whatsoever, directly or indirectly except in connection with the evaluation of the Program, without the prior written consent of the disclosing Party. As used herein, "use shall include, but not belimited to, and direct or indirect employment or application of such information in any research, experiment, development, or commercial enterprise.

3. The Parties agree that exchange of Confidential and Proprietary Information shall be limited solely to the Parties to this Agreement and disclosure outside these entities shall not be permitted without the prior written consent of the Disclosing Party.

4. Neither Party shall be liable for any use or disclosure of Confidential and Proprietary Information under the following circumstances:

Use or disclosure or such information which becomes a part of the public domain without the breach of this Agreement by the Receiving Party;

Use or disclosure of such information which the Receiving Party can clearly demonstrate by written evidence was known to it at the time of disclosure, or which the Receiving Party can demonstrate was developed by it completely independent of such information; and

Use or disclosure of such information obtained from third parties who lawfully acquired such information without restrictions as to its use or dissemination, and without breach of this Agreement.

5. ERICSSON RADIO SYSTEMS hereby agrees and acknowledges that QUALCOMM's specific implementation of CDMA Technology and Spread Spectrum techniques in conjunction with any telephone or cellular radio telephone or mobile radio product or service ("QUALCOMM's CDMA Technology") is proprietary to QUALCOMM. ERICSSON RADIO SYSTEMS hereby agrees that QUALCOMM's CDMA Technology includes, but is not limited to, QUALCOMM's techniques for soft handoff, interference control, voice activity detection, power control, multiple receivers for multipath mitigation and CDMA signal design including forward error correction, PN sequence generation, pilot carrier and CDMA synchronization. Further, in addition to QUALCOMM's CDMA Technology, the implementation of such a system including, but not limited to, interface information, shall remain QUALCOMM's Confidential and Proprietary Information and ERICSSON RADIO SYSTEMS shall not use this information in any other manner than permitted by this Agreement.

6. The Receiving Party agrees not to disclose Confidential and Proprietary Information received from the Disclosing Party to any of its employees other than those who have a need to know in connection with the evaluation of the Program, and agrees to inform such employees of the existance of this Agreement. Each party agrees to use the same degree of care with regard to Confidential and Proprietary Information as it employs with respect to its own information of like importance.

Without limiting the Disclosing Party's remedies, should the Receiving Party or any member of Receiving Party's organization conceive any invention having as its fundamental substance the Confidential and Proprietary Information, and principelly as a result or reviewing the Confidential and Proprietary Information, the Receiving Party agrees to assign or have assigned such invention to Disclosing Party.

7. This Agreement shall become effective on the date first set forth above, and except for the continuing obligations regarding use or disclosure of Confidential and Proprietary Information as herein set forth, shall terminate upon the happening of the earlier of:

(a) The written election by either Party to terminate this Agreement with or without cause, and such written election is delivered to the other;

b. The expiration of sixty (60) months from the date hereof.

8. Upon termination of this Agreement, the Receiving Party shall immediately return to that Disclosing Party all Confidential and Proprietary Information, including all copies, received under this Agreement from that Party, and shall certify in writing that all such information and copies of such information have been returned to the Disclosing Party.

9. Neither Party has made any commitment or is under any obligation to permit the other Party to use and Confidential and Proprietary Information disclosed hereunder, except as expressly set forth herein. This Agreement shall not be construed as itself creating any obligation on a Party to furnish information to the other Party or to enter into any agreement or relationship with respect to mutual business.

10. No license, copyright or other interest is granted directly or indirectly by the Disclosing Party as a result of conveying information to the Receiving Party, except the limited rights specifically provided herein.

11. Each Party hereby expressly acknowledges and agrees that its failure to comply with the provisions of this Agreement will cause irreparable harm and damage to the other Party for which the other Party will have no adequate remedy at law, and each Party further agrees that it shall not raise the repairability of harm or the adequacy of a remedy at law as a defense to any action brought by the other Party to enjoin the use of the Confidential and Proprietary Information or to obtain other equitable or legal relief.

12. In the event either Party shall bring any action to enforce or protect any of its rights under this Agreement, the prevailing Party shall be entitled to recover, in addition to its damages, its attorney's fees and costs.

13. Neither Party may assign or transfer, in while or in part, any of its rights, obligations or duties under this Agreement.

14. The provisions of this Agreement shall be governed by the laws of the State of California.

15. The provisions of this Agreement shall be severable, and should any provision or construction of any provision be held invalid, the remaining provisions hereof shall nevertheless remain in full force and effect.

16. The obligations under Sections 2,3,5, and 6 survive and shall be continuing upon any termination of this Agreement.

17. IN WITNESS WHEREOF, the Parties have caused this Agreement to be executed by their duly authorized representatives.

QUALCOMM, Inc.	ERICSSON RADIO SYSTEMS, INC.
A California Corporation	A Delaware Corporation
BY: [signature]	By: [signature]
Title: Vice Chairman	Title: President
Date: 12/4/87	Date: 12-1-87

JS 44
(Rev. 11/95)

CIVIL COVER SHEET

ORIGINAL

The JS-44 civil cover sheet and the information contained herein neither replace nor supplement the filing and service of pleadings or other papers as required by law, except as provided by local rules of court. This form, approved by the Judicial Conference of the United States in September 1974, is required for the use of the Clerk of Court for the purpose of initiating the civil docket sheet. (SEE INSTRUCTIONS ON THE REVERSE OF THE FORM.)

I. (a) PLAINTIFFS
QUALCOMM Incorporated

DEFENDANTS
TELEFONAKTIEBOLAGET LM ERICSSON, and ERICSSON, INC.

FILED
DEC 1996
CLERK, U.S. DISTRICT COURT
SOUTHERN DISTRICT OF CALIFORNIA
DEPUTY

(b) COUNTY OF RESIDENCE OF FIRST LISTED PLAINTIFF San Diego
(EXCEPT IN U.S. PLAINTIFF CASES)

COUNTY OF RESIDENCE OF FIRST LISTED DEFENDANT
(IN U.S. PLAINTIFF CASES ONLY)
NOTE: IN LAND CONDEMNATION CASES, USE THE LOCATION OF THE TRACT OF LAND INVOLVED

(c) ATTORNEYS (FIRM NAME, ADDRESS, AND TELEPHONE NUMBER)
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SAN DIEGO, CA 92121 (619) 550-6000

ATTORNEYS (IF KNOWN)

'962064 K CGA

'9620

II. BASIS OF JURISDICTION (PLACE AN "X" IN ONE BOX ONLY)

- [ ] 1 U.S. Government Plaintiff
- [X] 3 Federal Question (U.S. Government Not a Party)
- [ ] 2 U.S. Government Defendant
- [ ] 4 Diversity (Indicate Citizenship of Parties in Item III)

III. CITIZENSHIP OF PRINCIPAL PARTIES (PLACE AN "X" IN ONE BOX FOR PLAINTIFF AND ONE BOX FOR DEFENDANT)
(For Diversity Cases Only)

	PTF	DEF		PTF	DEF
Citizen of This State	[ ] 1	[ ] 1	Incorporated or Principal Place of Business in this State	[ ] 4	[ ] 4
Citizen of Another State	[ ] 2	[ ] 2	Incorporated and Principal Place of Business in Another State	[ ] 5	[ ] 5
Citizen or Subject of a Foreign Country	[ ] 3	[ ] 3	Foreign Nation	[ ] 6	[ ] 6

IV. ORIGIN (PLACE AN "X" IN ONE BOX ONLY)

- [X] 1 Original Proceeding
- [ ] 2 Removed from State Court
- [ ] 3 Remanded from Appellate Court
- [ ] 4 Reinstated or Reopened
- [ ] 5 Transferred from another district (specify)
- [ ] 6 Multidistrict Litigation
- [ ] 7 Appeal to District Judge from Magistrate Judgment

V. NATURE OF SUIT (PLACE AN "X" IN ONE BOX ONLY)

CONTRACT
- [ ] 110 Insurance
- [ ] 120 Marine
- [ ] 130 Miller Act
- [ ] 140 Negotiable Instrument
- [ ] 150 Recovery of Overpayment & Enforcement of Judgment
- [ ] 151 Medicare Act
- [ ] 152 Recovery of Defaulted Student Loans (Excl. Veterans)
- [ ] 153 Recovery of Overpayment of Veteran's Benefits
- [ ] 160 Stockholders' Suits
- [ ] 190 Other Contract
- [ ] 195 Contract Product Liability

REAL PROPERTY
- [ ] 210 Land Condemnation
- [ ] 220 Foreclosure
- [ ] 230 Rent Lease & Ejectment
- [ ] 240 Torts to Land
- [ ] 245 Tort Product Liability
- [ ] 290 All Other Real Property

TORTS

PERSONAL INJURY
- [ ] 310 Airplane
- [ ] 315 Airplane Product Liability
- [ ] 320 Assault, Libel & Slander
- [ ] 330 Federal Employers' Liability
- [ ] 340 Marine
- [ ] 345 Marine Product Liability
- [ ] 350 Motor Vehicle
- [ ] 355 Motor Vehicle Product Liability
- [ ] 360 Other Personal Injury

PERSONAL INJURY
- [ ] 362 Personal Injury-Med Malpractice
- [ ] 365 Personal Injury-Product Liability
- [ ] 368 Asbestos Personal Injury Product Liability

PERSONAL PROPERTY
- [ ] 370 Other Fraud
- [ ] 371 Truth in Lending
- [ ] 380 Other Personal Property Damage
- [ ] 385 Property Damage Product Liability

CIVIL RIGHTS
- [ ] 441 Voting
- [ ] 442 Employment
- [ ] 443 Housing/Accommodations
- [ ] 444 Welfare
- [ ] 440 Other Civil Rights

PRISONER PETITIONS
- [ ] 510 Motions to Vacate Sentence Habeas Corpus
- [ ] 530 General
- [ ] 535 Death Penalty
- [ ] 540 Mandamus & Other
- [ ] 550 Civil Rights

FORFEITURE/PENALTY
- [ ] 610 Agriculture
- [ ] 620 Other Food & Drug
- [ ] 625 Drug Related Seizure of Property 21 USC 881
- [ ] 630 Liquor Laws
- [ ] 640 R.R. & Truck
- [ ] 650 Airline Regs
- [ ] 660 Occupational Safety/Health
- [ ] 690 Other

LABOR
- [ ] 710 Fair Labor Standards Act
- [ ] 720 Labor/Mgmt. Relations
- [ ] 730 Labor/Mgmt. Reporting & Disclosure Act
- [ ] 740 Railway Labor Act
- [ ] 790 Other Labor Litigation
- [ ] 791 Empl. Ret. Inc. Security Act

BANKRUPTCY
- [ ] 422 Appeal 28 USC 158
- [ ] 423 Withdrawal 28 USC 157

PROPERTY RIGHTS
- [ ] 820 Copyrights
- [X] 830 Patent
- [ ] 840 Trademark

SOCIAL SECURITY
- [ ] 861 HIA (1395ff)
- [ ] 862 Black Lung (923)
- [ ] 863 DIWC/DIWW (405(g))
- [ ] 864 SSID Title XVI
- [ ] 865 RSI (405(g))

FEDERAL TAX SUITS
- [ ] 870 Taxes (U.S. Plaintiff or Defendant)
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OTHER STATUTES
- [ ] 400 State Reapportionment
- [ ] 410 Antitrust
- [ ] 430 Banks and Banking
- [ ] 450 Commerce/ICC Rates/etc
- [ ] 460 Deportation
- [ ] 470 Racketeer Influenced and Corrupt Organizations
- [ ] 810 Selective Service
- [ ] 850 Securities/Commodities/Exchange
- [ ] 875 Customer Challenge 12 USC 3410
- [ ] 891 Agricultural Acts
- [ ] 892 Economic Stabilization Act
- [ ] 893 Environmental Matters
- [ ] 894 Energy Allocation Act
- [ ] 895 Freedom of Information Act
- [ ] 900 Appeal of Fee Determination Under Equal Access to Justice
- [ ] 950 Constitutionality of State Statutes
- [ ] 890 Other Statutory Actions

VI. CAUSE OF ACTION (CITE THE U.S. CIVIL STATUTE UNDER WHICH YOU ARE FILING AND WRITE A BRIEF STATEMENT OF CAUSE. DO NOT CITE JURISDICTIONAL STATUTES UNLESS DIVERSITY.) DECLARATORY RELIEF REGARDING VARIOUS U.S. PATENTS AND RELATED STATE CLAIMS

VII. REQUESTED IN COMPLAINT: [ ] CHECK IF THIS IS A CLASS ACTION UNDER F.R.C.P. 23
DEMAND $ According to Proof
CHECK YES only if demanded in complaint:
JURY DEMAND: [X] YES [ ] NO

VIII. RELATED CASE(S) IF ANY (See instructions): JUDGE ________ DOCKET NUMBER ________

DATE 12/5/96
SIGNATURE OF ATTORNEY OF RECORD
STEPHEN P. SWINTON

FOR OFFICE USE ONLY

RECEIPT # ________ AMOUNT ________ APPLYING IFP ________ JUDGE ________ MAG. JUDGE ________

20637

AO 440 (Rev. 10/93) Summons in a Civil Action

United States District Court

SOUTHERN DISTRICT OF CALIFORNIA

QUALCOMM Incorporated

SUMMONS IN A CIVIL ACTION

CASE NUMBER: 96 2064 K CGA

V.

TELEFONAKTIEBOLAGET LM ERICSSON, and
ERICSSON, INC.,

TO: (Name and Address of Defendant)

YOU ARE HEREBY SUMMONED and required to file with the Clerk of this Court and serve upon

PLAINTIFF'S ATTORNEY (name and address)

Stephen P. Swinton, Esq. (106398)
Cooley Godward LLP
4365 Executive Drive
Suite 1100
San Diego, CA 92121-2128

an answer to the complaint which is herewith served upon you, within 20 days after service of this summons upon you, exclusive of the day of service. If you fail to do so, judgment by default will be taken against you for the relief demanded in the complaint.

ROBERTA WESTDAL
CLERK

DEC - 5 1996
DATE

SEAL

Ron Ann Bressi

AO-440S

AO 120 (3/85)

TO: Commissioner of Patents and Trademarks Washington, D.C. 20231	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT

In compliance with the Act of July 19, 1952 (66 Stat. 814; 35 U.S.C. 290) you are hereby advised that a court action has been filed on the following patent(s) in the U.S. District Court:

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
96cv2064 K(CGA)	12/5/96	United States District Court, Southern District of California
PLAINTIFF Qualcomm, Inc.		DEFENDANT Telefonaktiebolaget LM Ericsson
PATENT NO.	DATE OF PATENT	PATENTEE
1 5,430,760	7/4/95	Ericsson GE Mobile Communications, Inc.
2 5,551,073	8/27/96	Ericsson Inc.
3 5,193,140	3/9/93	Telefonaktiebolaget LM Ericsson
4		
5		

In the above-entitled case, the following patent(s) have been included:

DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading	
PATENT NO.	DATE OF PATENT	PATENTEE
1		
2		
3		
4		
5		

In the above-entitled case, the following decision has been rendered or judgment issued:

DECISION/JUDGMENT		
CLERK	(BY) DEPUTY CLERK J. Laviolette	DATE 12/12/96

Copy 1 - Upon initiation of action, mail this copy to Commissioner Copy 3 - Upon termination of action, mail this copy to Commissioner

Copy 2 - Upon filing document adding patent(s), mail this copy to Commissioner Copy 4 - Case file copy

AO 120 (3/85)

TO: Commissioner of Patents and Trademarks Washington, D.C. 20231	REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT

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